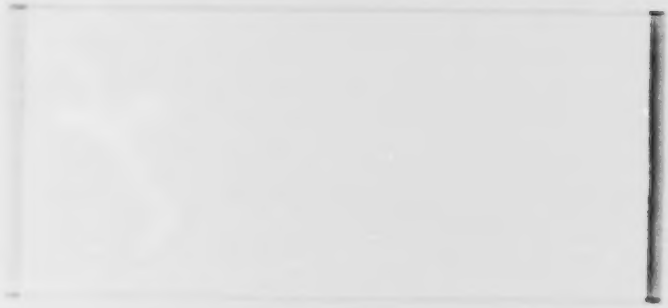

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TP 7174E 186

EVALUATION OF PADS AND INSULATORS FOR USE ON CONCRETE TIES

Prepared for

TRANSPORT CANADA

TRANSPORTATION DEVELOPMENT CENTRE

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October 1985

The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transportation Development Centre (TDC) of Transport Canada.

Un sommaire en français de ce rapport est inclus avant la table des matières.

REPORT DOCUMENTATION FORM

1. Transport Canada Report No.	2. TDC Project No.	3. Recipient's Catalogue No.
TP 7174E	4929	

4. Title and Subtitle	5. Report Date
EVALUATION OF PADS AND INSULATORS FOR USE ON CONCRETE TIES	October 1985
	6. Performing Organization Report No. 186

7. Author(s)	8. Transport Canada File No.
J.F. Scott - Senior Research Engineer J.W. McDonald - Senior Engineering Assistant	D1465-404

9. Performing Organization Name and Address	10. DSS File No.
CN Technical Research Centre 3950 Hickmore Ave. St. Laurent, Quebec H4T 1K2	12SD.T8200-2-2586
	11. DSS or Transport Canada Contract No. OSD83-00002

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Transportation Development Centre (TDC) Guy Favreau Complex 200 Dorchester Blvd. W., Suite 601, West Tower Montreal, Quebec H2Z 1X4	Final; 1980-1984
	14. Sponsoring Agency Code TDC 4929

15. Supplementary Notes	16. TDC Project Officer
CN Research and Transportation Development Centre equally shared in the cost of this program.	D.W. Dibble

17. Abstract

Pads are required between base of rail and top surface of concrete ties to provide electrical insulation and to prevent pulverization of concrete. Insulators are required between edge of rail base and iron shoulders cast in the concrete to provide electrical insulation between rails and ties, this being necessary to maintain integrity of rail signal systems. Insulators and soft rail/tie pads installed on CN's mountain region were failing prematurely and a research project aimed at improving the situation was initiated. Many different types of insulator and pad materials were evaluated in the laboratory. This report summarizes the results of the tests conducted. Wide variations were found in pad properties and pad fatigue lives. It was not possible, however, to define those specific properties which would guarantee long pad life because there were no consistently repeatable correlations between pad life and pad properties. Some trends were definitely indicated, but there appeared to be exceptions. Of the twenty types of insulators tested, nine were equal to or better than the ones currently used by CN Rail. Fatigue testing should continue until there is total failure of the pads, instead of restricting the tests to a fixed number of cycles.

Testing of impact loading attenuation requirements of pads for concrete ties was also initiated. It was concluded that more research on this and other aspects of pad and insulator development is required.

18. Key Words	19. Distribution Statement
Concrete tie pads, insulators, physical properties, stiffnesses, fatigue life	Copies available from Transportation Development Centre

20. Security Classification (of this report)	21. Security Classification (of this page)	22. No. of Pages	23. Price
Unclassified	Unclassified	130	--

TDC CDT 79-005

FORMULE DE DOCUMENTATION POUR RAPPORT

1. Nº du rapport Transports Canada	2. Nº de l'étude — CDT	3. Nº de catalogue du destinataire
TP 7174E	4929	

4. Titre et sous-titre	5. Date du rapport
EVALUATION OF PADS AND INSULATORS FOR USE ON CONCRETE TIES	octobre 1985
	6. Nº du rapport de l'organisme exécutant: 186

7. Auteur(s)	8. Nº de dossier Transports Canada
J.F. Scott - Ingénieur recherche J.W. McDonald - Assistant métallurgiste	D1465-404

9. Nom et adresse de l'organisme exécutant	10. Nº de dossier — ASC
Canadien National Centre de recherche CN Rail 3950 avenue Hickmore Saint-Laurent, Québec H4T 1K2	12SD.T8200-2-2586
	11. Nº de contrat — ASC ou Transports Canada: OSD83-00002

12. Nom et adresse de l'organisme parrain	13. Genre de rapport et période visée
Centre de développement des transports (CDT) Complexe Guy-Favreau 200 ouest, boul. Dorchester, Suite 601, Tour ouest Montréal, Québec H2Z 1X4	Final; 1980-1984
	14. Code de l'organisme parrain: CDT 4929

15. Remarques additionnelles	16. Agent de projet — CDT
Le Centre de recherche CN Rail et le Centre de développement des transports contribuent à parts égales au coût des travaux de recherche.	D.W. Dibble

17. Résumé

Ce rapport rend compte des travaux concernant l'étude des semelles placées entre les rails et les traverses en béton, dans le double but de réaliser l'isolement électrique des rails et de protéger le béton contre l'épaufrement. Il concerne aussi les joints isolats qu'il faut placer entre le bord du patin de rail et le rebord de la selle métallique encastrée dans le béton, joints assurant la continuité électrique des signaux de retour. Il avait été constaté que les joints isolants et les semelles en caoutchouc souple équipant les voies du CN dans les régions montagneuses connaissaient une défaillance précoce. Une recherche a donc été faite pour remédier à cet état de choses. Ce rapport récapitule le compte rendu des essais en laboratoire faits sur divers matériaux. Dans le cas des semelles, d'importants écarts ont été constatés tant au niveau des caractéristiques physiques que de la résistance à la fatigue. Vu l'absence de corrélation cohérente et répétable entre caractéristiques et résistance à la fatigue des matériaux essayés, il n'a pas été possible de dégager des caractéristiques particulières garantissant des durées de vie intéressantes. Des tendances ont pu être dégagées, mais des exceptions ont aussi été notées. Sur la vingtaine de joints isolants testés, neuf ont eu un comportement égal ou supérieur aux matériaux couramment utilisés par CN Rail. Il est recommandé de poursuivre les essais de résistance à la fatigue des semelles jusqu'à ruine totale et de ne pas arrêter les essais au bout d'un nombre de cycles donné.

Des essais visant à caractériser les qualités d'amortissement requises des semelles ont été également faits. Ils ont permis de constater la nécessité de recherches plus poussées tant dans ce domaine que dans des domaines connexes.

18. Mots-clés	19. Diffusion
Semelles pour traverses en béton, joints isolants, caractéristiques physiques, raideur, résistance à la fatigue	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

20. Classification de sécurité (de ce rapport)	21. Classification de sécurité (de cette page)	22. Nombre de pages	23. Prix
non classifié	non classifiée	130	—

CDT TDC 79-005

ACKNOWLEDGEMENTS

The Authors gratefully acknowledge the assistance of Mr. P. Paley, Chemist, and Mr. T. Johns, Senior Laboratory Assistant, in developing much of the information contained in this report.

EXECUTIVE SUMMARY

Since the introduction of concrete ties into main line track curves, there has been a need to develop a pad for insertion between the rail base and the concrete tie rail seat, and an insulator for insertion between the rail base edge and the cast iron shoulder of the concrete tie, both of which would stand up to the pressures of the vertical and lateral forces exerted on them from the rolling stock. The pads have to be soft enough to attenuate the loads, and yet hard enough to withstand the heavy pressures and abrasion from the rail movements. Insulators have to be hard enough to withstand the lateral forces exerted on them, and durable enough to withstand abrasion from the longitudinal and lateral rocking movements of the rail.

In 1982 and 1983, CN prepared specifications for both soft and hard pads. These specifications listed the physical requirements for pads that were to be used on concrete ties. However, it was also necessary to evaluate the life endurance of pads and insulators. This was done on an inclined loading fatigue test machine, which imparts a vertical and lateral force simultaneously to the rails under which the pads and insulators are placed. This test, although a little more severe than actual service conditions, serves very well in evaluating the pads and insulators in an accelerated, but comparable manner. However, since few manufacturers have such equipment available, it required research work to see if it was possible to relate the measured fatigue life of the pads and insulators with their physical properties.

This report describes a series of laboratory tests undertaken:

- to evaluate various pads for compliance with the CN specifications;
- to determine if there was a relationship between fatigue test performance and the measurable physical properties of the pads;
- to evaluate the fatigue life of various insulators in order to determine their suitability for track use.

The laboratory tests performed on the pads indicate that load/deflection and fatigue tests give the best results in rating pad performance, whereas the physical properties tests are not too useful in rating pads. But the research was unable to establish a relationship between the physical properties and the fatigue life of pads. It was also found that the present CN method of testing load/deflection of the pads does not give a complete picture: the test results show pad stiffness, but do not give an indication of the pad's rate of recovery after being compressed.

The inclined loading fatigue test set-up on a rail seat appears to provide the best method of predicting relative service lives of pads and insulators. Although it requires specialized equipment, this test has the distinct advantage of being able to identify pads and insulators that would develop premature failures in track.

The results of the laboratory fatigue tests indicate that the number of cycles applied to the pads was insufficient to properly evaluate the life expectancy of the pads. Based on CN Rail traffic on the British Columbia south line (approximately two million axles per year with roughly 35% heavy axle loads), about 0.7 million heavy axle load cycles per year are applied to each tie. Pads used in main line curves should last at least three years, which is the life expectancy of the rails, and should not have to be removed until the rails are. Therefore, the number of cycles that the pads should be subjected to is 3 x 0.7 million cycles, or a minimum of two million cycles without failure.

Another test that can be used to evaluate pads is the impact attenuations test, which is done by dropping an instrumented wheel-set onto a rail section under which the pad has been placed. CN Research laboratories are looking into a simpler impact test for pad evaluation. Pads that could pass the above tests would then be subjected to all of the physical properties tests, and the results used in establishing specifications for both hard and soft pads used with concrete ties.

SOMMAIRE

Depuis l'introduction des traverses en béton pour équiper les voies en courbe des grandes lignes ferroviaires, la nécessité s'est fait sentir de pouvoir disposer de semelles et de joints isolants capable de résister aux forces verticales et transversales exercées sur eux par le passage des trains rapides. C'est par l'intermédiaire de la semelle que le rail repose sur une traverse en béton, tandis que le joint isolant se trouve placé entre le bord du patin de rail et le rebord de la selle métallique encastrée dans la traverse. On demande aux semelles d'être suffisamment souples pour absorber les charges verticales et suffisamment dures pour résister aux importantes forces exercées par le passage des trains ainsi qu'aux forces d'usure. Quant aux joints, ils doivent être suffisamment durs pour résister aux charges transversales et avoir l'endurance voulue face aux mouvements horizontaux et transversaux imprimés aux rails.

En 1982 et 1983, le CN a élaboré un cahier des charges concernant les caractéristiques physiques attendues des semelles, tant souples que dures, devant équiper les voies reposant sur des traverses en béton. Mais il fallait aussi connaître la résistance à la fatigue des divers matériaux pouvant entrer dans la fabrication des semelles et des joints. Cette détermination a été faite à l'aide d'une machine d'essais sous charge oblique qui, simultanément, exerce une charge verticale et transversale sur un tronçon de rails équipés de semelles et de joints. Bien que cet essai impose des conditions un peu plus rigoureuses que dans la réalité, il demeure très utile pour évaluer la résistance à la fatigue des semelles et des joints de manière accélérée dans des conditions comparables. Toutefois, comme peu de fabricants disposent d'un tel appareillage, il a fallu vérifier s'il était possible de trouver une corrélation entre les caractéristiques physiques des matériaux et leur résistance à la fatigue établie.

Le présent rapport concerne les essais de laboratoire visant à:

- déterminer la conformité de divers types de semelle au cahier des charges du CN,
- trouver une corrélation entre les caractéristiques physiques mesurables des matériaux utilisés et leur résistance à la fatigue établie par les tests précités;
- déterminer la résistance à la fatigue de divers types de joints et leur adéquation au service ferroviaire.

Les essais en laboratoire ont permis de constater que les essais visant à déterminer les courbes contrainte-déformation et la résistance à la fatigue des semelles permettent de mieux prévoir la tenue des matériaux en service que les essais de détermination des caractéristiques physiques des matériaux utilisés. Par contre, il n'a pas été possible d'établir une corrélation entre les caractéristiques physiques de ceux-ci et leur résistance à la fatigue. En outre, durant les essais, il a été constaté que la méthode préconisée par le CN pour établir les courbes contrainte-déformation des matériaux de semelles renseigne uniquement sur la raideur de ces matériaux et ne fournit aucune indication sur leur taux de reprise après compression.

La méthode d'essais par charge oblique des fixations de traverse semble être le meilleur moyen de prédire la limite de fatigue des semelles et des joints. Bien qu'elle exige un appareillage spécialisé, elle permet de déceler les matériaux qui risquent de moins bien résister en service.

En ce qui concerne les essais de résistance à la fatigue des semelles, il a été établi que le nombre des cycles d'application de la charge était insuffisant pour évaluer correctement la durée de vie des semelles. Connaissant la nature du trafic ferroviaire franchissant les voies du CN dans le sud de la Colombie-Britannique (quelque deux millions d'essieux par an, dont 35 p. 100 environ de trafic lourd), on a calculé qu'une traverse subit quelque 700 000 cycles de surcharge lourde par an. Or, il faudrait que les semelles équipant les voies en courbe aient une durée de vie d'au moins trois années, durée qui correspond à celle des rails eux-mêmes, de manière que, le moment venu, semelles et rails puissent être déposés en même temps. Il en résulte que les semelles devraient pouvoir résister sans ruine à trois fois 700 000 cycles, ou au moins deux millions de cycles.

Un autre essai utile est celui visant à déterminer l'amortissement dynamique. Il consiste à laisser choir un essieu monté instrumenté sur un tronçon de voie équipé des semelles à tester. Mais le bureau de recherches du CN espère trouver une méthode plus simple que celle-ci. Ayant franchi la batterie d'essais précités, les semelles seraient ensuite soumises aux essais de détermination des caractéristiques physiques, le résultat de tous ces essais débouchant sur une norme qui définirait avec précision les exigences concernant les matériaux tant souples que durs entrant dans la fabrication des semelles.

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1. INTRODUCTION

In order to evaluate material used in manufacture of pads for concrete ties, a series of tests was devised, and the minimum and maximum values of the physical properties of the pads were set out in CN specifications 12-10 and 12-15. Specification 12-10 covers the requirements for hard pads made from carbon-filled ethylene vinyl acetate (EVA) polymer, and Specification 12-15 covers the requirements for soft pads made from carbon-filled styrene-butadiene rubber (SBR). It was also required that the pads and insulators be tested for life endurance. This was done on an inclined loading fatigue test machine, which imparts a vertical and lateral force simultaneously to the rails under which the pads and insulators are placed. This test, although a little more severe than tual service conditions, serves very well in evaluating the pads and insulators in an accelerated, but comparable manner. However, since few manufacturers have such equipment available, it required research work to see if it was possible to relate the life expectancy of the pads and insulators with their physical properties. This work has been carried out for the past few years and the results are contained in this report.

2. CONCLUSIONS

2.1 Only one out of the 24 pads tested to the CN specification was able to meet all of the requirements for physical properties.

2.2 Three of the soft pads failed to meet the minimum requirements for static stiffness, twelve of the seventeen soft pads had a static stiffness greater than the maximum required. Two of the pads were within specification for static stiffness.

2.3 Six out of the seven hard pads tested had a static stiffness greater than the maximum required. The remaining pad was within the specification for static stiffness.

2.4 A comparison test, between the CN test method and Supplier D's test method for static load/deflection test on pads, showed that Supplier D's test method indicated the pads to be softer by 2.97% for the Supplier A's soft pads, and 10.7% softer for the Supplier A's hard pads. In general, tie pads of 5 mm thickness are so stiff that significant variations in test results can be introduced by the variable stiffnesses of the testing machines

2.5 The static stiffness of Supplier A's hard pad can be reduced by as much as 44.3% by machining a series of grooves on both sides of the pad without apparent loss of fatigue life.

2.6 The present set-up for fatigue testing pads and insulators is more than adequate and was used for 22 out of the 39 tests conducted up to the present time.

2.7 Six out of the twelve pads, used to determine a relationship between the fatigue tests and the physical properties of the pads, were in the same condition after fatigue testing, however, there were considerable differences in their physical properties.

2. CONCLUSIONS (cont'd)

2.8 Out of twenty types of insulators tested, nine were equal to or better than the A-5 insulators currently used by CN Rail.

2.9 There were wide variations in pad properties and pad fatigue lives. It was not possible, however, to define those specific pad properties which would guarantee a long pad life because there were no consistently repeatable correlations between pad life and pad properties. Some trends were definitely indicated but there appeared to be exceptions to every "rule".

2.10 The inclined loading fatigue test set-up on a rail seat (vertical load V = 32.5 kips, lateral load L = 16.9 kips, ratio L/V = 0.52) appears to provide the best method of predicting pad and insulator relative service lives. While specialized equipment is required to run this test, it has the distinct advantage of being able to weed out materials which would develop premature failures in track.

3. RECOMMENDATIONS

3.1 There should be a re-evaluation of present specifications 12-10 and 12-15 for hard and soft pads. It will, perhaps, require the raising and/or lowering of some of the requirements based on the tests done to date.

3.2 Supplier D's test method should be used for static load/deflection tests. This method would allow use of deflectometers, instead of dial gauges, to measure pad deflections, thereby making it possible to plot the load/deflection curves directly, a much more accurate method of reporting test results.

3.3 Fatigue testing should continue until there is total failure of the pads, instead of restricting the tests to a fixed number of cycles. This should be done on pads that had good physical condition following the fatigue tests, and had physical properties that could meet at least 60% of the specified requirements. This work may help to establish a better relationship between fatigue test results and physical properties of the pads.

3.4 Supplier A's grooved hard pad should be fatigue tested until total failure. Termination of the fatigue test after some pre-selected number of cycles does not provide useful comparative data, especially if the pad is still in good condition at cessation of test.

4. PURPOSE

The purpose of these laboratory tests was:

4.1 To evaluate various pads for compliance with the CN specifications 12-10 for hard pads, and 12-15 for soft pads.

4.2 To determine if there was a relationship between fatigue test performance and the measurable physical properties of the pads.

4.3 To evaluate the fatigue life of various insulators in order to determine their suitability for track use.

5. METHODOLOGY

The physical and chemical tests carried out on the pads, submitted for evaluation, were in accordance with the following test methods.

TENSILE STRENGTH	A.S.T.M. test method D-412 for soft pads, and D-638 for hard pads.
ELONGATION	A.S.T.M. test method D-412 for soft pads and D-638 for hard pads.
AGING TEST	Seven days at 70°C in air. A.S.T.M. method D-412 for soft pads.
DENSITY	A.S.T.M. test method D-792 for hard pads.
COMPRESSION SET	25% compression for 24 hours at 70°C A.S.T.M. test method D-395, method B for soft and hard pads. This method used a 29.0 mm die, 3 thicknesses of pads and a 30-minute recovery time.
DUROMETER HARDNESS	A.S.T.M. test method D-2240 for soft and hard pads.
ASH CONTENT	A.S.T.M. test method D-297 for soft pads, and D-229 for hard pads.
OIL RESISTANCE	72 hours at 23 ± 2°C using A.S.T.M. oil No. 3, CN test method, specification 12-15 for soft pads.
ELECTRICAL RESISTANCE	A.S.T.M. test method D-257 for soft and hard pads.
ABRASION LOSS	Taber abrasion using H-22 wheels with 1000 g load for 1000 cycles. CN test method, spec 12-15 for soft pads and spec 12-10 for hard pads.
LOW TEMPERATURE FLEXIBILITY	CN test method spec 12-15 for soft pads. Pad must be bent back on itself at -40°C without cracking.

5. **METHODOLOGY** (cont'd)

LOAD/DEFLECTION

CN test method, spec 12-15 for soft pads and spec 12-10 for hard pads. This test was done with full size pads. The test method requires the pad to be compressed between two smooth heavy steel plates rigid enough to prevent any bending, and of a suitable area to cover the pad. Four dial guages, one midway on each side of the plates, measures the deflection of the pad under load. See Photograph No. 1.

The manufacturer D's test method was done with a full size pad compressed between a rail section, long enough to cover the pad, and a smooth steel plate. Two dial gauges, one at each end of the rail section measured the deflection of the pad under load. See Photograph No. 2.

FATIGUE TEST

The fatigue tests were carried out on the CN Research Centre inclined loading fatigue machine. Assembly of this test set-up consists of bolting two cast steel tie plates, with manufacturer A's shoulders, to the machine table, setting them apart 20", center to center. The rail seat areas of both plates are coated with an epoxy cement mixed with a silicon sand. This was done to simulate the rough surface of the concrete ties. The pads are placed on the tie-plates under the rails, and the insulators are placed between the rail base edges and the tie-plate shoulders. The whole assembly is held together with Manufacturer A's clips. The hydraulic actuator applies a load of 65.0 kips, which is transmitted through four inclined load arms to the rail heads,

5. **METHODOLOGY** (cont'd)

FATIGUE TEST

giving a vertical load of 32.5 kips, and a lateral load of 16.9 kips (ratio L/V = 0.52) to each rail assembly. The hydraulic loads are cycled between 1.0 and 65.0 kips at a rate of 2 C.P.S. This set-up allows two tests to be run at the same time. Photograph No. 3 shows the inclined load fatigue testing machine.

6. TEST RESULTS

The test work done on the pads and insulators submitted for evaluation was divided into seven sections and the results of this work was as follows:

SECTION NO. 1

There were a total of twenty tests carried out to determine the physical properties of the pads submitted for evaluation. Table No. 1 lists the performance of the pads, rated as a percentage of the number of tests meeting the requirements of the CN specifications 12-10 and 12-15. It should be noted that the supplier A's pads samples 1 and 2 were the types that were used to develop the CN specifications 12-10 and 12-15. Table No. 2 lists the actual test results and compares them to the CN specifications.

SECTION NO. 2

The submitted sample pads were compressed with several compression loads up to a maximum of 60,000 lbs, and the deflection of pads recorded. The static stiffness of each pad was then calculated from the test results. Table No. 3 lists the pads in ascending order of stiffness. Tables No. 4 and 16 give the actual load/deflection test results of the pads submitted for testing. Figures No. 1 to 13 show the plotted results. Table No. 17 shows the load/deflection test results on pads that were tested using the CN test method, but instead of using only four load points to plot the graphs, loads were applied to the pads in 500 lb increments up to 4,000 lbs, then every 1,000 lbs up to 10,000 lbs then every 5,000 lbs up to 30,000 lbs, and then every 10,000 lbs to the maximum load of 60,000 lbs. The test results are illustrated in Figure No. 14. Table No. 18 shows the test results on similar pads as above, but using the manufacturer 'D' test method. Figure No. 15 shows the results and Figure No. 16 compares the two test methods. Photographs Nos 1 and 2 show both of the test methods.

6. TEST RESULTS (cont'd)

SECTION NO. 3

Three different groove patterns were machined into two of Supplier A's sample No. 2 hard pads in order to try to reduce the static stiffness of the pads, without loss of fatigue life. Tables No. 19, 20 and 21 list the results of the load/deflection tests on the Supplier A, sample No. 2 pad with the different grooved patterns. They also give the change in static stiffness and list the dimensions of the grooves. Figure No. 17 shows the plotted test results. Figures Nos 18, 19 and 20 illustrate the groove patterns. It should be noted that the Supplier A's sample No. 2 pad with the groove pattern "C" was fatigue tested to 504,000 cycles without failure.

SECTION NO. 4

The fatigue test results on pads submitted for evaluation are shown in Table No. 22. It should be noted, however, that there were some changes made in the test equipment, and they were as follows:

From test No. 6 to test No. 17 the pads were fatigue tested on concrete rail seat sections grouted into a steel box, with the rail seats set 22 inches apart. Test No. 18 and all other tests were concluded on cast steel tie plates with shoulders and rail seats spaced 20 inches apart. A silica sand embedded in an epoxy cement was used to coat the rail seat surface in order to simulate the roughness of the concrete. Test No. 18 and all subsequent tests were carried out on this test set-up.

During the tests No. 6 to 15, temperature measurements of the pad under the rail were taken and it was noted that pad temperatures varied between 21.0 and 29.5°C (not a significant temperature rise).

Checking for electrical ground, between the rail fastening system and the rail, was used to determine when there was failure of either the pads or insulators. This procedure was adopted for test No. 10 and all other tests thereafter. After test No. 19, fatigue testing was restricted to a maximum of approximately 500,000 cycles in order to speed up evaluation program.

6. **TEST RESULTS** (cont'd)

SECTION NO. 5

Table No. 23 shows the length, width and thickness of the pads before and after fatigue testing. Table No. 24 shows the differences in weight and hardness after fatigue testing. Figure No. 21 shows the locations where the different measurements were made.

SECTION NO. 6

Four physical properties of the pads, considered most related to the fatigue life of the pads, were used to try and establish a relationship between the physical properties and the fatigue performance life of the pads . Table No. 25 lists the physical properties, the number of fatigue loading cycles and the condition of the pads at the end of the fatigue tests. Figures No. 22, 23, 24 and 25 show the different relationships, and Table No. 26 lists the different related pad conditions. The Photographs Nos 4 and 5 show a new pad, rated 10, and a severely damaged pad, rated 1. This visual and subjective rating system was adopted in order to try and rank the various levels of fatigue damage.

SECTION NO. 7

Under the same fatigue test condition for pads, the insulators were tested and Table No. 27 lists the various insulators tested, the total number of fatigue cycles and the condition of the insulators at the end of the tests. Table No. 28 summarizes the fatigue tests, and it should be noted, however, that some of the tests were terminated without failure at approximately 500,000 cycles, specifically the tests with Supplier A insulators.

7. DISCUSSION

The work done to date on pads shows that the load/deflection and the fatigue tests are the only ones that give the best results in rating pad performance. It appears that the physical properties test on the pads are not too useful in rating the pads, nor is there an established relationship between the physical properties and fatigue life of the pads.

The present CN test method for load/deflection tests on the pads, described in the methodology, does not give a complete picture. All the CN results show is the pad stiffness, what is also required, is to know the pad rate of recovery after having been compressed. In order to measure this hysteresis, the Supplier D's test method is the best one to use; however, instead of using dial gauges, two deflectometers could be used. The output from these deflectometers would be summed, then averaged, and the resultant along with the load applied fed into an x-y plotter. The plotted curve would give the pad stiffness for any given deflection, and would also show the pad's ability to recover from the applied compression load. The larger the hysteresis, the greater amount of energy retained by the pad. What is required is a pad with little or no hysteresis.

It has already been stated, in this report, that the number of fatigue cycles applied to the pads was insufficient to give a proper evaluation of the life expectancy of the pads. Based on the traffic which CN Rail carries on the British Columbia south line (approximately two million axles per year with roughly 35% heavy axle loads), about 0.7 million heavy axle load cycles per year are applied to each tie. Pads, used in main line curves, should last at least three years, which is the life expectancy of the rails, and should not have to be removed until there is rail removal. Therefore, the number of cycles that the pads should be tested to is 3 x 0.7 million cycles, or a minimum of two million cycles without failure.

7. **DISCUSSION** (cont'd)

There is another test that should be used in evaluation of the pads and that is the Impact Attenuations test. At the present time this test is done by dropping an instrumented wheel-set onto a rail section under which the pad has been placed. The pad is sitting in place in the rail seat area of the concrete tie the test results have not been promising. It would appear that a simpler impact test must be developed. The CN Research laboratories are presently looking into this aspect of pad evaluation.

Pads that could pass the above tests would then be subjected to all of the physical properties tests, and the results used in establishing specifications for both hard and soft pads, for use with concrete ties. Pandrol International, U.K., is currently carrying out extensive research into pad specification requirements. The A.R.E.A. committee 10 - Concrete ties, currently has a sub-committee assignment to specify an appropriate pad impact attenuations test.

The best hard pad, tested in the laboratory, was the Supplier A's hard pad sample No. 2, and one of the better soft pads was the same supplier's sample No. 1 pad. Both these pads are being used in service at the present time. However, the soft pad has a short service life, especially when used in curves. The hard pad, which is performing very well in service, is also causing concern in that it may be too hard to properly attenuate the loads that are applied to the rails and concrete ties. It was therefore decided to try and reduce this pad's stiffness by machining grooves into the pad. The pad was then subjected to 500,000 fatigue cycles, and it performed well, however, it remains to be seen if the pad can endure 2,000,000 fatigue cycles without failure. This work is being done at the present time.

The best of the insulators tested was the Supplier A's sample No. 6, which endured 2,000,000 fatigue cycles without failure. This insulator is being field tested at the present time. The majority of the failures occurred in the vertical post of the insulators. The failure of the posts is caused by the applied compressive stress under repeated abrasive fatigue loading. The compressive stresses on the posts is calculated as follows:

7. **DISCUSSION** (cont'd)

$$S = (L/V - \frac{\mu V}{V}) V$$

$$= (L/V - \mu)$$

where S = Compression load in Kips
L/V = Lateral force divided by the vertical force, which is 0.52 in the laboratory tests
μ = Coefficient of friction
V = Applied vertical load, which is the laboratory test this load = 32.5 Kips, in the field this load = 22.0 Kips

Therefore the load applied to the post in the laboratory test is 32.5 Kips (0.52 - 0.3) = 7.15 Kips, and in the field this load would be 22.0 Kips (0.52 - 0.3) = 4.84 Kips. The area of the vertical post is (3/8" x 3") = 1.125 in^2, therefore the compressive stresses on the vertical post would be 4.30 ksi in the field and 6.36 ksi in the laboratory test. The requirement, therefore, for the insulators would be that the material used in construction of the insulators would have to withstand a minimum of 5 ksi under repeated abrasive fatigue loadings. In comparison it should be noted that the pads are subjected to a compressive load of 1230 P.S.I. in laboratory testing.

Much has been accomplished in evaluating pads and insulators for use with concrete ties, however, some problems remain, and this we are presently attempting to solve.

TABLE NO. 1

PHYSICAL PROPERTIES OF PADS

Pad Supplier Lab Identification	Sample No.	Type of Pad	No. of Tests	% Passing Specified Requirements
A	1	Soft	20	100.0
B	1	Soft	19	73.7
C	1	Soft	19	63.2
D	2	Soft	19	63.2
G	1	Soft	19	63.2
H	1	Soft	19	63.2
E	1	Soft	20	60.0
D	1	Soft	20	60.0
D	3	Soft	20	55.0
E	2	Soft	19	52.6
E	3	Soft	19	52.6
J	3	Soft	19	52.6
F	1	Soft	14	50.0
H	2	Soft	20	50.0
I	2	Soft	18	50.0
J	2	Soft	19	47.4
I	1	Soft	18	38.9
A	2	Hard	20	85.0
C	2	Hard	20	60.0
J	1	Hard	19	57.9
K	1	Hard	18	55.6
K	2	Hard	18	55.6
D	4	Hard	14	42.9
L	2	Hard	19	52.6

NOTE: Total number of test requirements = 20

TABLE NO. 2

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	A-2	A-1	B-1	F-1	K-1
Tensile Strength, lb/in.	1800 ±200	1450 min.	1930	1490	1555	Not Tested	7800
Elongation at break, %	450 - 650	275 min.	575	300	400	Not Tested	287
Modulus at 100% of Elongation, lbs/in.	800 - 1000	450 min.	810	540	602	Not Tested	6750
Aging 7 days at 70°C in air: - tensile strength % of "As Received"	--	90 min.	106	112	97	Not Tested	122
Elongation at break % of "As Received"	--	85 - 105	129	104	88	Not Tested	35
Compression set, % of original deflection	80 - 95	40 max.	78	20	58	21	72
Shore hardness	32 - 40(D)	66 - 70(A)	32(D)	69(A)	82(A)	70(A)	75(D)
Hardness change after 5 hours exposure, %							
at -20°C (- 4°F)	+20D max	+12A max.	+12(D)	+4	+12	+5	+6
at -30°C (-22°F)	+25D max	+22A max.	+19	+18	+13	+7	+7
at -40°C (-40°F)	+30D max	+30A max.	+27	+26	+15	+11	+7

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	A-2	A-1	B-1	F-1	K-1
Loss on abrasion (Taber) H22 wheel, 1000 g, 1000 cycles - Mg	50 mg max	260 mg max	21	250	Not Tested	421	584 100% 405 R.H. 305 wet
Ash content, %	0.3 max	15 max	0.25	12.7	4.3	24.6	0.5
Oil resistance, 72 hours at 20°C - volume change %	--	+20 max	+2.0	10.5	+8.2	+23.8	0
Shore hardness (change from original hardness)	--	-10 max	-2(D)	-8	-4	-10	0
Load/Deflection test							
Deflection (inches)							
at 4000 lb. load	0.005 max	0.004 - 0.006	0.0043	0.0042	0.0034	0.0063	0.0006
at 20000 lb. load	0.007 max	0.017 - 0.020	0.0061	0.0178	0.0155	0.0284	0.0019
at 60000 lb. load	0.007 to 0.014	0.020 - 0.024	0.0077	0.0216	0.0205	0.0412	0.0030
Static stiffness (between 4000 and 20,000 lbs) - million lbs/in.	8.000 max	1.000 - 1.455	8.889	1.176	1.322	0.724	12.308
Low temperature flexibility at -40°C	--	No Cracks	flexes	com-plies	com-plies	com-plies	Not Tested

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	A-2	A-1	B-1	F-1	K-1
Pad thickness - mm	--	--		4.5	5.0		
* Fatigue test (No. of cycles) to Failure	without 500,000	failure min.	501,030 to 1,745,500	79,080 to 4,708,080	43,970	186,810	Not Tested

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	C-2	C-1	J-1	J-2	J-3
Tensile Strength, lb/in	1800 ±200	1450 min.	7780	1610	1870	935	1060
Elongation at break, %	450 - 650	275 min.	333	275	150	275	222
Modulus at 100% of Elongation, lbs/in	800 - 1000	450 min.	2340	516	1665	580	775
Aging 7 days at 70°C in air: - tensile strength % of "As Received"	--	90 min.	95	92	99	82	111
Elongation at break % of "As Received"	--	85 - 105	99	91	89	61	94
Compression set, % of original deflection	80 - 95	40 max.	30	7	51	31	44
Shore hardness	32 - 40(D)	66 - 70A	53(D)	65(A)	48(D)	75(A)	26(D)
Shore hardness change after 5 hours exposure, %							
at -20°C (- 4°F)	+20D max	+12A max.	+17	+4	+16	+18	+19
at -30°C (-22°F)	+25D max	+22A max.	+19	+10	+24	+21	+26
at -40°C (-40°F)	+30D max	+30A max.	+23	+20	+24	+2	+29

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	C-2	C-1	J-1	J-2	J-3
Loss on abrasion (Taber) H22 wheel, 1000 g, 1000 cycles - Mg	50 mg max.	260 mg max.	29	288	50	270	200
Ash content, %	0.3 max	15 max	0	2.0	5.6	11.6	10.2
Oil resistance, 72 hours at 20°C - volume change %	--	+20 max	0	+3.6	+1.6	+6.4	+4.6
Shore hardness (change from original hardness)	--	-10 max	0	-3	-4(D)	-1(A)	-2(D)
Load/Deflection test							
Deflection (inches)							
at 4000 lb. load	0.005 max	0.004 - 0.006	0.0018	0.0018	0.0030	0.0025	0.0045
at 20000 lb. load	0.007 max	0.017 - 0.020	0.0115	0.0035	0.0046	0.0035	0.0223
at 60000 lb. load	0.007 to 0.014	0.020 - 0.024	0.0157	0.0157	0.0054	0.0100	0.0274
Static stiffness (between 4000 and 20,000 lbs) - million lbs/in.	8.000 max	1.000 - 1.455	1.649	9.412	10.000	16.000	0.899

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	C-2	C-1	J-1	J-2	J-3
Low temperature flexibility at -40°C	--	No cracks	slightly flexible	complies	slightly flexible	flexible	flexible
Pad thickness - mm			4.4		5.0	5.0	5.0
* Fatigue test (No. of cycles) to Failure	without failure 500,000 min.		Not Tested	Not Tested	Not Tested	Not Tested	Not Tested

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	D-3	D-1	D-4	D-2	L-2
Tensile Strength, lb/in	1800 ±200	1450 min.	1,540	1,950	1,863	1.540	6,600
Elongation at break, %	450 - 650	275 min.	137	275	41	137	320
Modulus at 100% of Elongation, lbs/in.	800 - 1000	450 min.	1,250	1,270	Not Tested	1,250	1,510
Aging 7 days at 70°C in air: - tensile strength % of "As Received"	--	90 min.	109	106	Not Tested	128	96
Elongation at break % of "As Received"	--	85 - 105	137	82	Not Tested	129	110
Compression set, % of original deflection	80 - 95	40 max.	14	14	64	Not Tested	18
Shore hardness	32 - 40(D)	66 - 70A	83(A)	83(A)	58(D)	83(A)	47(D)
Hardness change after 5 hours exposure, %							
at -20°C (- 4°F)	+20D max	+12A max.	+4	+7	+22	+4	+23
at -30°C (-22°F)	+25D max	+22A max.	+9	+9	+24	+8	+35
at -40°C (-40°F)	+30D max	+30A max.	+13	+13	+26	+12	+38

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	D-3	D-1	D-4	D-2	L-2
Loss on abrasion (Taber) H22 wheel, 1000 g, 1000 cycles - Mg	50 mg max.	260 mg max.	591	420	322	494	202
Ash content, %	0.3 max	15 max	31.7	33.0	21.8	31.8	0
Oil resistance, 72 hours at 20°C - volume change %	--	+20 max	+9.7	+9	Not Tested	+9.3	+6
Shore hardness (change from original hardness)	--	-10 max	-4	-7	Not Tested	-6	+1
Load/Deflection test							
Deflection (inches)							
at 4000 lb. load	0.005 max	0.004 - 0.006	0.0057	0.0025	0.0004	0.0045	0
at 20000 lb. load	0.007 max	0.017 - 0.020	0.0311	0.0062	0.0003	0.0125	0.0005
at 60000 lb. load	0.007 to 0.014	0.020 - 0.024	0.0456	0.0118	0.0011	0.0244	0.0019
Static stiffness (between 4000 and 20,000 lbs) - million lbs/in.	8.000 max	1.000 - 1.455	0.630	4.320	22.900	2.000	32.000

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	D-3	D-1	D-4	D-2	L-2
Low temperature flexibility at -40°C	--	No cracks	complies	complies	Not Tested	complies	stiff
Pad thickness - mm				5.0	5.0		5.0
* Fatigue test (No. of cycles)	500,000	min.	340,330	503,120 without failure	653,510 without failure	525,010 without failure	Not Tested

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs 12-10 Hard	CN Specs *12-15 Soft	Test Results E-2	E-3	E-1	H-2	H-1
Tensile Strength, lb/in	1800 ±200	1450 min.	930	1,100	3,200	1,650	1,372
Elongation at break, %	450 - 650	275 min.	87	25	400	200	175
Modulus at 100% of Elongation, lbs/in.	800 - 1000	450 min.	--	--	605	1,442	1,032
Aging 7 days at 70°C in air: - tensile strength % of "As Received"	--	90 min.	97	128	84	84	103
Elongation at break % of "As Received"	--	85 - 105	100	268	69	62	93
Compression set, % of original deflection	80 - 95	40 max.	77	23	28	11	23
Shore hardness	32 - 40(D)	66 - 70A	88(A)	84(A)	78(A)	82(A)	82(A)
Hardness change after 5 hours exposure, %							
at -20°C (- 4°F)	+20D max	+12A max.	+7	+3	+ 7	+4	+4
at -30°C (-22°F)	+25D max	+22A max.	+8	+7	+17	+10	+10
at -40°C (-40°F)	+30D max	+30A max.	+8	+9	+19	+12	+12

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	E-2	E-3	E-1	H-2	H-1
Loss on abrasion (Taber) H22 wheel, 1000 g, 1000 cycles - Mg	50 mg max.	260 mg max.	472	636	53	310	310
Ash content, %	0.3 max	15 max	24.2	28.5	2.2	4.5	2.2
Oil resistance, 72 hours at 20°C - volume change %	--	+20 max	-0.6	+0.6	+16.1	+3.0	+3.0
Shore hardness (change from original hardness)	--	-10 max	+2	-14	+1	-2	-2
Load/Deflection test							
Deflection (inches)							
at 4000 lb. load	0.005 max	0.004 - 0.006	0.0030	0.0005	0.0010	0.0004	0.0008
at 20000 lb. load	0.007 max	0.017 - 0.020	0.0056	0.0020	0.0032	0.0029	0.0047
at 60000 lb. load	0.007 to 0.014	0.020 - 0.024	0.0073	0.0030	0.0101	0.0135	0.0228
Static stiffness (between 4000 and 20,000 lbs) - million lbs/in.	8.000 max	1.000 - 1.455	6.154	10.670	7.273	6.400	4.103

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results				
	12-10 Hard	*12-15 Soft	E-2	E-3	E-1	H-2	H-1
Low temperature flexibility at -40°C	--	No cracks	complies	complies	complies	stiff	stiff
Pad thickness - mm							
* Fatigue test (No. of cycles)	without 500,000	failure min.	595,810 without failure	675,920 without failure	646,160 without failure	490,020	Not Tested

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results			
	12-10 Hard	*12-15 Soft	I-1	I-2	K-2	G-1
Tensile Strength, lb/in	1800 ±200	1450 min.	675	1,220	7,800	637
Elongation at break, %	450 - 650	275 min.	18	25	287	225
Modulus at 100% of Elongation, lbs/in.	800 - 1000	450 min.	--	--	6,750	451
Aging 7 days at 70°C in air: - tensile strength % of "As Received"	--	90 min.	117	105	122	108
Elongation at break % of "As Received"	--	85 - 105	175	124	35	103
Compression set, % of original deflection	80 - 95	40 max.	29	37	72	27
Shore hardness	32 - 40(D)	66 - 70A	78(A)	86(A)	75(D)	75(A)
Hardness change after 5 hours exposure, %						
at -20°C (- 4°F)	+20D max	+12A max.	+14	+11	+6	+11
at -30°C (-22°F)	+25D max	+22A max.	+25	+22	+7	+16
at -40°C (-40°F)	+30D max	+30A max.	+37	+32	+7	+20

* Proposed

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results			
	12-10 Hard	*12-15 Soft	I-1	I-2	K-2	G-1
Loss on abrasion (Taber) H22 wheel, 1000 g, 1000 cycles - Mg	50 mg max.	260 mg max.	138	131	584) 100% 405) R.H. 305) wet	485
Ash content, %	0.3 max	15 max	4.0	4.6	0.5	12.6
Oil resistance, 72 hours at 20°C - volume change %	--	+20 max	+6.4	+9.8	0	+13.4
Shore hardness (change from original hardness)	--	-10 max	-1	-5	0	-6
Load/Deflection test						
Deflection (inches)						
at 4000 lb. load	0.005 max	0.004 - 0.006	0.0028	0.0020	0.0006	0.0005
at 20000 lb. load	0.007 max	0.017 - 0.020	0.0064	0.0066	0.0019	0.0041
at 60000 lb. load	0.007 to 0.014	0.020 - 0.024	0.0140	0.0077	0.0030	0.0213
Static stiffness (between 4000 and 20,000 lbs) - million lbs/in.	8.000 max	1.000 - 1.455	4.444	3.478	12.308	**4.444

* Proposed
** Average of 3 tests

TABLE NO. 2 (cont'd)

PHYSICAL PROPERTIES OF PADS

Material Tests	CN Specs		Test Results			
	12-10 Hard	*12-15 Soft	I-1	I-2	K-2	G-1
Low temperature flexibility at -40°C	--	No cracks	complies	complies	Not tested	complies
Pad thickness - mm					5.0	
* Fatigue test (No. of cycles)	500,000	min.	Not tested	Not tested	Not tested	Not tested

* Proposed

TABLE NO. 3

STATIC STIFFNESS OF PADS

(Assumed linear between 4,000 and 20,000 lb. load)

Pad Status	Pad Supplier	Sample No.	Chemical Identification	Lab No.	Static Stiffness (M lbs/in)
soft	D	3	Styrene butadiene rubber	1	0.630
soft	F	1	Natural rubber mix	1	0.724
soft	F	1	Natural rubber mix	2	0.724
soft	J	3	Natural rubber and styrene	6	0.860
soft	J	3	Butadiene rubber	3	0.899
soft	B	1	Neoprene	2	1.111
soft	A	1	Styrene butadiene	1	1.185
soft	A	1	Rubber	2	1.203
soft	A	1	Rubber	3	1.280
soft	B	1	Neoprene	1	1.322
soft	J	2	Natural rubber and styrene butadiene rubber	5	1.481
soft	D	2	Styrene butadiene rubber	1	2.000
soft	I	2	Natural rubber and polyethylene fibres	4	3.478
soft	H	1	Neoprene blend (polyester and chlorobutal)	1	4.103
soft	G	1	Butadiene and natural rubber	2	4.571

TABLE NO. 3 (cont'd)

STATIC STIFFNESS OF PADS

(Assumed linear between 4,000 and 20,000 lb. load)

Pad Status	Pad Supplier	Sample No.	Chemical Identification	Lab No.	Static Stiffness (M lbs/in)
soft	D	1	Styrene butadiene rubber and natural rubber	1	4.324
soft	I	1	Natural rubber and polyethylene fibres	3	4.444
soft	G	1	Butadiene and natural rubber	1	4.571
soft	G	1	Butadiene and natural rubber	3	4.571
soft	I	1	Natural rubber and polyethylene fibres	4	6.154
soft	E	2	Fibre reinforced vinyl	1	6.154
soft	H	2	Neoprene blend (polyester and chlorobutal)	1	6.400
soft	E	1	Carboxylated nitrile	1	7.243
soft	C	1	Neoprene	1	9.412
soft	I	2	Natural rubber and polyethylene fibres	2	10.667
soft	E	3	Fibre reinforced natural rubber	1	10.667
soft	J	2	Natural rubber and styrene butadiene rubber	2	16.000
hard	L	2	Polysulphide clear	2	∿Infinite
hard	C	2	Polyurethane	1	1.649

TABLE NO. 3 (cont'd)

STATIC STIFFNESS OF PADS

(Assumed linear between 4,000 and 20,000 lb. load)

Pad Status	Pad Supplier	Sample No.	Chemical Identification	Lab No.	Static Stiffness (M lbs/in)
hard	A	2	Ethylene vinyl acetate	1	9.412
hard	A	2	Ethylene vinyl acetate	2	10.000
hard	J	1	Natural rubber and styrene butadiene rubber	1	10.000
hard	M	1	Urethane	1	10.667
hard	K	1	Nylon	1	12.308
hard	J	1	Natural rubber and styrene butadiene rubber	4	17.778
hard	L	1	Polysulphide clear	3	20.000
hard	D	4	Styrene butadiene rubber	1	22.857
hard	L	1	Polysulphide clear	1	32.000

TABLE NO. 4

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches		
	Supplier L Sample 2 Lab No. 1	Supplier L Sample 2 Lab No. 2	Supplier L Sample 2 Lab No. 3
60,000	Applied six times		
500	0.0000	0.0000	0.0000
4,000	0.0000	0.0000	0.0003
20,000	0.0005	0.0000	0.0011
60,000	0.0019	0.0012	0.0025
Static Stiffness million lbs/in.	32.000	∿Infinite	20.000

TABLE NO. 5

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches			
	Supplier D Sample 2 Lab No. 1	Supplier D Sample 3 Lab No. 1	Supplier D Sample 1 Lab No. 1	Supplier D Sample 4 Lab No. 1
60,000	Applied six times			
500	0.0000	0.0000	0.0000	0.0000
4,000	0.0045	0.0057	0.0025	-0.0004
20,000	0.0125	0.0311	0.0062	0.0003
60,000	0.0244	0.0456	0.0118	0.0011
Static Stiffness million lbs/in.	2.000	0.630	4.324	22.857

TABLE NO. 6

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches		
	Supplier J Sample 1 Lab No. 1	Supplier J Sample 2 Lab No. 2	Supplier J Sample 3 Lab No. 3
60,000	Applied six times		
500	0.0000	0.0000	0.0000
4,000	0.0030	0.0025	0.0045
20,000	0.0046	0.0035	0.0223
60,000	0.0054	0.0100	0.0274
Static Stiffness million lbs/in.	10.000	16.000	0.899

TABLE NO. 6 (cont'd)

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches		
	Supplier J Sample 1 Lab No. 4	Supplier J Sample 2 Lab No. 5	Supplier J Sample 3 Lab No. 6
60,000	Applied six times		
500	0.0000	0.0000	0.0000
4,000	0.0018	0.0028	0.0041
20,000	0.0027	0.0136	0.0227
60,000	0.0031	0.0230	0.0276
Static Stiffness million lbs/in.	17.778	1.481	0.860

TABLE NO. 7

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches		
	Supplier C Sample 2 Lab No. 1	Supplier C Sample 1 Lab No. 1	Supplier K Sample 1 Lab No. 1
60,000	Applied six times		
500	0.0000	0.0000	0.0000
4,000	0.0018	0.0018	0.0006
20,000	0.0115	0.0035	0.0019
60,000	0.0157	0.0157	0.0030
Static Stiffness million lbs/in.	1.649	9.412	12.308

TABLE NO. 8

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches		
	Supplier E Sample 2 Lab No. 1	Supplier E Sample 3 Lab No. 1	Supplier E Sample 1 Lab No. 1
60,000	Applied six times		
500	0.0000	0.0000	0.0000
4,000	0.0030	0.0005	0.0010
20,000	0.0056	0.0020	0.0032
60,000	0.0073	0.0030	0.0101
Static Stiffness million lbs/in.	6.154	10.667	7.273

TABLE NO. 9

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches	
	Supplier I Sample 2 Lab No. 2	Supplier I Sample 2 Lab No. 4
60,000	Applied six times	
500	0.0000	0.0000
4,000	0.0018	0.0020
20,000	0.0033	0.0066
60,000	0.0079	0.0079
Static Stiffness million lbs/in.	10.667	3.478

TABLE NO. 10

PADS - LOAD/DEFLECTION TESTS

	Pad Deflection - Inches	
Applied Load (lbs)	Supplier A Sample 2 Lab No. 1	Supplier A Sample 2 Lab No. 2
60,000	Applied six times	
500	0.0000	0.0000
4,000	0.0043	0.0037
20,000	0.0060	0.0053
60,000	0.0077	0.0068
Static Stiffness million lbs/in.	9.412	10.000

TABLE NO. 11

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches	
	Supplier H Sample 2 Lab No. 1	Supplier H Sample 1 Lab No. 1
60,000	Applied six times	
500	0.0000	0.0000
4,000	0.0004	0.0008
20,000	0.0029	0.0047
60,000	0.0135	0.0228
Static Stiffness million lbs/in.	6.400	4.103

TABLE NO. 12

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches	
	Supplier I Sample 1 Lab No. 1	Supplier I Sample 1 Lab No. 2
60,000	Applied six times	
500	0.0000	0.0000
4,000	0.0021	0.0028
20,000	0.0047	0.0064
60,000	0.0070	0.0140
Static Stiffness million lbs/in.	6.154	4.444

TABLE NO. 13

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches		
	Supplier G Sample 1 Lab No. 1	Supplier G Sample 1 Lab No. 2	Supplier G Sample 1 Lab No. 3
60,000	Applied six times		
500	0.0000	0.0000	0.0000
4,000	0.0005	0.0006	0.0005
20,000	0.0040	0.0044	0.0040
60,000	0.0225	0.0204	0.0211
Static Stiffness million lbs/in.	4.571	4.211	4.571

TABLE NO. 14

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches	
	Supplier B Sample 1 Lab No. 1	Supplier B Sample 1 Lab No. 2
60,000	Applied six times	
500	0.0000	0.0000
4,000	0.0034	0.0059
20,000	0.0155	0.0203
60,000	0.0205	0.0259
Static Stiffness million lbs/in.	1.322	1.111

TABLE NO. 15

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches		
	Supplier A Sample 1 Lab No. 1	Supplier A Sample 1 Lab No. 2	Supplier A Sample 1 Lab No. 3
60,000	Applied six times		
500	0.0000	0.0000	0.0000
4,000	0.0039	0.0051	0.0038
20,000	0.0172	0.0176	0.0173
60,000	0.0204	0.0218	0.0218
Static Stiffness million lbs/in.	1.203	1.280	1.185

TABLE NO. 16

PADS - LOAD/DEFLECTION TESTS

Applied Load (lbs)	Pad Deflection - Inches	
	Supplier F Sample 1 Lab No. 1	Supplier F Sample 1 Lab No. 2
60,000	Applied six times	
500	0.0000	0.0000
4,000	0.0063	0.0063
20,000	0.0284	0.0284
60,000	0.0387	0.0412
Static Stiffness million lbs/in.	0.724	0.724

TABLE NO. 17

PAD LOAD/DEFLECTION TESTS

CN TEST METHOD

Applied Load (lbs)	Pad Deflection - Inches					
	Supplier A's Pad Sample No. 1			Supplier A's Pad Sample No. 2		
	Pad and Plates	Plates Only	Pad Only	Pad and Plates	Plates Only	Pad Only
60,000	Applied six times					
500	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1000	0.0009	0.0003	0.0006	0.0014	0.0003	0.0011
1500	0.0019	0.0005	0.0014	0.0021	0.0005	0.0016
2000	0.0028	0.0006	0.0022	0.0026	0.0006	0.0020
2500	0.0036	0.0008	0.0028	0.0029	0.0008	0.0021
3000	0.0045	0.0010	0.0035	0.0032	0.0010	0.0022
3500	0.0052	0.0011	0.0041	0.0035	0.0011	0.0024
4000	0.0060	0.0012	0.0048	0.0037	0.0012	0.0025
5000	0.0074	0.0014	0.0060	0.0041	0.0014	0.0027
6000	0.0087	0.0015	0.0072	0.0045	0.0015	0.0030
7000	0.0101	0.0016	0.0085	0.0048	0.0016	0.0032

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TABLE NO. 17 (cont'd)

PAD LOAD/DEFLECTION TESTS

CN TEST METHOD

Applied Load (lbs)	Pad Deflection - Inches					
	Supplier A's Pad Sample No. 1			Supplier A's Pad Sample No. 2		
	Pad and Plates	Plates Only	Pad Only	Pad and Plates	Plates Only	Pad Only
8000	0.0113	0.0017	0.0096	0.0050	0.0017	0.0033
9000	0.0124	0.0019	0.0105	0.0053	0.0019	0.0034
10000	0.0135	0.0019	0.0116	0.0056	0.0019	0.0037
15000	0.0177	0.0024	0.0153	0.0066	0.0024	0.0042
20000	0.0204	0.0024	0.0180	0.0074	0.0024	0.0050
25000	0.0218	0.0029	0.0189	0.0079	0.0029	0.0050
30000	0.0226	0.0031	0.0195	0.0084	0.0031	0.0053
40000	0.0227	0.0033	0.0194	0.0093	0.0033	0.0060
50000	0.0250	0.0035	0.0215	0.0111	0.0035	0.0066
60000	0.0276	0.0036	0.0240	0.0112	0.0036	0.0076
Static Stiffness million lbs/in.	1.212			6.400		

TABLE NO. 18

PAD LOAD/DEFLECTION TESTS

SUPPLIER D TEST METHOD

Applied Load (lbs)	Pad Deflection - Inches					
	Supplier A's Pad Sample No. 1			Supplier A's Pad Sample No. 2		
	Pad and Plates	Plates Only	Pad Only	Pad and Plates	Plates Only	Pad Only
60,000	Applied six times					
500	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1000	0.0011	0.0002	0.0009	0.0005	0.0002	0.0003
1500	0.0023	0.0003	0.0020	0.0009	0.0003	0.0006
2000	0.0035	0.0003	0.0032	0.0012	0.0003	0.0009
2500	0.0047	0.0005	0.0042	0.0014	0.0005	0.0009
3000	0.0058	0.0005	0.0053	0.0017	0.0005	0.0012
3500	0.0067	0.0006	0.0061	0.0019	0.0006	0.0013
4000	0.0077	0.0007	0.0070	0.0021	0.0007	0.0014
5000	0.0094	0.0008	0.0086	0.0024	0.0008	0.0016
6000	0.0111	0.0009	0.0102	0.0027	0.0009	0.0018
7000	0.0130	0.0010	0.0120	0.0030	0.0010	0.0020

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TABLE NO. 18 (cont'd)

PAD LOAD/DEFLECTION TESTS

SUPPLIER D TEST METHOD

Applied Load (lbs)	Pad Deflection - Inches					
	Supplier A's Pad Sample No. 1			Supplier A's Pad Sample No. 2		
	Pad and Plates	Plates Only	Pad Only	Pad and Plates	Plates Only	Pad Only
8000	0.0146	0.0011	0.0135	0.0033	0.0011	0.0022
9000	0.0157	0.0012	0.0145	0.0036	0.0012	0.0024
10000	0.0172	0.0012	0.0160	0.0038	0.0012	0.0026
15000	0.0208	0.0016	0.0192	0.0051	0.0016	0.0035
20000	0.0224	0.0018	0.0206	0.0060	0.0018	0.0042
25000	0.0241	0.0021	0.0220	0.0070	0.0021	0.0049
30000	0.0257	0.0023	0.0234	0.0081	0.0023	0.0058
40000	0.0291	0.0026	0.0265	0.0101	0.0026	0.0075
50000	0.0348	0.0028	0.0320	0.0124	0.0028	0.0096
60000	0.0440	0.0031	0.0409	0.0149	0.0031	0.0118
Static Stiffness million lbs/in.	1.176			5.714		

TABLE NO. 19

LOAD/DEFLECTION TESTS ON GROOVED PAD

SUPPLIER A, SAMPLE NO. 2 PAD

GROOVED PATTERN "A"

Pad Deflection - Inches

Applied Load (lbs)	Compression Plates and Pad	Compression Plates Only	Pad Only
60,000	Applied six times		
500	0.0000	0.0000	0.0000
4,000	0.0045	0.0014	0.0031
20,000	0.0108	0.0029	0.0079
60,000	0.0231	0.0038	0.0193

Static Stiffness M.lbs/in. = 2.540

NOTE: Slots were cut out of the solid PAD on one side only. Dimensions of the slots were as follows:

Width = 3/8"
Depth = 1/2 the pad thickness
Length = length of the pad = 7 1/2"

TABLE NO. 20

LOAD/DEFLECTION TESTS ON GROOVED PAD

SUPPLIER A, SAMPLE NO. 2 PAD

GROOVED PATTERN "B"

Applied Load (lbs)	Pad Deflection - Inches		
	Compression Plates and Pad	Compression Plates Only	Pad Only
60,000	Applied six times		
500	0.0000	0.0000	0.0000
4,000	0.0039	0.0013	0.0026
20,000	0.0126	0.0030	0.0096
60,000	0.0302	0.0039	0.0263

Static Stiffness M.lbs/in. = 2.286

NOTE: Slots were cut out of the solid PAD on both sides. Dimensions of the slots are as follows:

Width (Side No. 1)	=	3/8"
Width (Side No. 2)	=	1/8"
Depth of slots	=	1/2 the pad thickness
Slot length	=	pad length = 7 1/2"

TABLE NO. 21

LOAD/DEFLECTION TESTS ON GROOVED PAD

SUPPLIER A, SAMPLE NO. 2 PAD

GROOVED PATTERN "C"

Applied Load (lbs)	Pad Deflection - Inches		
	Compression Plates and Pad	Compression Plates Only	Pad Only
60,000	Applied six times		
500	0.0000	0.0000	0.0000
4,000	0.0052	0.0015	0.0037
20,000	0.0113	0.0036	0.0077
60,000	0.0241	0.0051	0.0190

Static Stiffness M.lbs/in. = 1.416

NOTE: Slots were cut out of the solid Pad, both sides. Dimensions of the slots are as follows:

Width (both sides)	=	3/16"
Depth	=	1/2 the pad thickness
Length	=	length of pad = 7 1/2"

TABLE NO. 22

PADS - FATIGUE TESTS

Inclined Loading, V = 32.5 Kips, L = 19.5 Kips, L/V = 0.60
per rail seat

Test No.	Pad Identification	Test Location	Total No. of Cycles	Comments
6	Supplier A sample No. 1	* Side A	1,028,170	O.K.
6	Supplier A sample No. 1	Side B	1,028,170	O.K.
7	Supplier A sample No. 1	* Side A	4,708,080	Plastic flow pad through under insulator.
7	Supplier A sample No. 1	Side B	708,080	Pad failed. Large plastic flow, notched and torn.
7	Supplier A sample No. 1	Side B	4,000,000	New pad. Some plastic flow.
8	Supplier A sample No. 2	Side A	1,745,500	Some plastic flow.
8	Supplier A sample No. 1	Side B	1,745,500	Plastic flow, splitting of pad at tie shoulder.
10	Supplier A sample No. 2	Side A	1,687,120	Badly worn.
10	Supplier A sample No. 2	Side B	3,901,199	Some abrasion only.
10	Supplier A sample No. 2	Side A	2,285,630	New pad. Some abrasion only.
11	Supplier A sample No. 2	Side A	1,258,640	

* Same pad - total cycles = 5,736,250

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TABLE NO. 22 (cont'd)

PADS - FATIGUE TESTS

Inclined Loading, V = 32.5 Kips, L = 19.5 Kips, L/V = 0.60
per rail seat

Test No.	Pad Identification	Test Location	Total No. of Cycles	Comments
11	Supplier A sample No. 2	Side B	1,258,640	
15	Supplier A sample No. 2	Side A	358,430	O.K.
15	Supplier A sample No. 2	Side B	358,430	O.K.
16	Supplier A sample No. 1	Side A	2,725,520	O.K.
16	Supplier A sample No. 2	Side B	2,725,520	O.K.
17	Supplier A sample No. 2	Side A	1,267,820	O.K.
17	Supplier A sample No. 2	Side B	1,267,820	O.K.

NOTE: Tests 15 to 17 used the same pads for a total of 3,626,250 cycles. These tests were conducted using a different rail fastening system.
Tests 6 to 17 were conducted on concrete tie rail seat sections, grouted into a steel box with rail seats set at 22" centers.

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TABLE NO. 22 (cont'd)

PADS - FATIGUE TESTS

Inclined Loading, V = 32.5 Kips, L = 16.9 Kips, L/V = 0.52
per rail seat

Test No.	Pad Identification	Test Location	Total No. of Cycles	Comments
18	Supplier A sample No. 1	Side A	816,400)	* Preliminary test, new test set-up.
18	Supplier A sample No. 1	Side B	816,400)	
19	Supplier A sample No. 1	Side A	1,069,840	O.K.
19	Supplier A sample No. 1	Side B	1,069,840	O.K.
20	Supplier A sample No. 1	Side A	648,250)	Work with strain gaged Pandrol clip
20	Supplier A sample No. 1	Side B	648,250)	
21	Supplier A sample No. 1	Side A	189,230	O.K.
21	Supplier A sample No. 1	Side B	189,230	Pad failed.
22	Supplier A sample No. 1	Side A	88,700	Slight wear.
22	Supplier A sample No. 1	Side B	88,700	Pad failed.
23	Supplier A sample No. 1	Side A	79,080	Pad badly worn.

NOTE: * Malleable cast iron tie plates were used instead of concrete ties. A silica sand embedded in an epoxy cement on the rail seat was used to simulate the concrete surface. Rail seat spacing was 20" center.

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TABLE NO. 22 (cont'd)

PADS - FATIGUE TESTS

Inclined Loading, V = 32.5 Kips, L = 16.9 Kips, L/V = 0.52
per rail seat

Test No.	Pad Identification	Test Location	Total No. of Cycles	Comments
23	Supplier A sample No. 1	Side B	79,080	O.K. new test set-up.
24	Supplier H sample No. 2	Side A	9,430)	Machine overload. Destroyed pads.
24	Supplier H sample No. 2	Side B	9,430)	
25	Supplier H sample No. 2	Side A	490,020	Pad failed.
25	Supplier H sample No. 2	Side B	490,020	Pad failed
26	Supplier A sample No. 2	Side A	501,030	O.K.
26	Supplier A sample No. 2	Side B	501,030	O.K.
27	Supplier B sample No. 1	Side A	43,970	Pad failed.
27	Supplier B sample No. 1	Side B	43,970	Pad failed.
28	Supplier D sample No. 2	Side A	503,120	O.K.
28	Supplier D sample No. 2	Side B	503,120	O.K.
29	Supplier D sample No. 4	Side A	653,510	O.K.

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TABLE NO. 22 (cont'd)

PADS - FATIGUE TESTS

Inclined Loading, V = 32.5 Kips, L = 16.9 Kips, L/V = 0.52
per rail seat

Test No.	Pad Identification	Test Location	Total No. of Cycles	Comments
29	Supplier D sample No. 4	Side B	653,510	O.K.
30	Supplier D sample No. 3	Side A	340,330	O.K.
30	Supplier D sample No. 3	Side B	340,330	Pad failed.
31	Supplier F sample No. 1	Side A	186,810	Pad failed.
31	Supplier F sample No. 1	Side B	186,810	Pad failed
32	Supplier E sample No. 1	Side A	646,160	O.K.
32	Supplier E sample No. 1	Side B	646,160	O.K.
33	Supplier E sample No. 3	Side A	675,920	O.K.
33	Supplier E sample No. 3	Side B	675,920	O.K.
34	Supplier E sample No. 2	Side A	595,810	O.K.
34	Supplier E sample No. 2	Side B	595,810	O.K.
35	Supplier A sample No. 2	Side A	536,810	O.K.

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TABLE NO. 22 (cont'd)

PADS - FATIGUE TESTS

Inclined Loading, V = 32.5 Kips, L = 16.9 Kips, L/V = 0.52
per rail seat

Test No.	Pad Identification	Test Location	Total No. of Cycles	Comments
35	Supplier A sample No. 2	Side B	536,810	O.K.
36	Supplier A sample No. 2	Side A	894,050	O.K.
36	Supplier A sample No. 2	Side B	894,050	O.K.
37	Supplier A sample No. 2	Side A	504,100	O.K. Pad slotted to reduce stiffness (wide slots).
37	Supplier A sample No. 2	Side B	504,100	O.K. Pad slotted to reduce stiffness (narrow slots).
38	Supplier A sample No. 2	Side A	503,000	O.K.
38	Supplier A sample No. 2	Side B	503,000	O.K.
39	Supplier A sample No. 2	Side A	596,090	O.K. Still under test. Same pads test No. 40.
39	Supplier A sample No. 2	Side B	596,090	O.K. Still under test. Same pads test No. 40.

TABLE NO. 23

PADS - DIMENSIONAL CHECK

DISTORTION OF PADS FOLLOWING FATIGUE TEST

Test No.	Pad Ident.	Fatigue Cycles	LENGTH - INCHES									WIDTH - INCHES								
			End 1			Middle			End 2			End 1			Middle			End 2		
			Before	After	Diff %	Before	After	Diff %	Before	After	Diff %	Before	After	Diff %	Before	After	Diff %	Before	After	Diff %
36 Side A	Supplier A sample 2	894,050	.189	.190	+0.5	.189	.190	+0.5	.1895	.1895	.000	.190	.191	+0.5	.1625	.163	+0.3	.1905	.1915	+0.5
36 Side B	Supplier A sample 2	894,050	.189	.1895	+0.3	.189	.1895	+0.3	.189	.190	+0.5	.1905	.191	+0.3	.1625	.1625	Nil	.1905	.191	+0.3
30 Side A	Supplier D sample 3	340,330	.178	.178	Nil	.178	.179	+0.6	.1785	.179	+0.3	.191	.192	+0.5	.168	.166	-1.2	.191	.191	Nil
30 Side B	Supplier D sample 3	340,330	.178	.178	Nil	.178	.1785	+0.3	.178	.1785	+0.3	.190	.191	+0.5	.167	.170	+1.8	.1905	.191	+0.3
26 Side A	Supplier A sample 2	501,030	.189	.189	Nil	.189	.190	+0.5	.189	.191	+1.1	.1905	.1915	+0.5	.1625	.163	+0.3	.1905	.191	+0.3
26 Side B	Supplier A sample 2	501,030	.1895	.190	+0.3	.1895	.190	+0.3	.1895	.191	+0.8	.191	.1915	+0.3	.1625	.164	+0.9	.191	.191	Nil
28 Side A	Supplier D sample 2	503,120	.177	.180	+1.7	.1775	.178	+0.3	.1775	.179	+0.9	.197	.198	+0.5	.1675	.169	+0.9	.197	.198	+0.5
28 Side B	Supplier D sample 2	503,120	.1785	.180	+0.8	.1785	.179	+0.3	.1785	.181	+1.4	.197	.197	Nil	.1685	.168	-0.3	.197	.198	+0.5
33 Side A	Supplier E sample 3	675,920	.1915	.192	+0.3	.1915	.192	+0.3	.1915	.1915	Nil	.180	.180	Nil	.150	.1505	+0.3	.180	.180	Nil
33 Side B	Supplier E sample 3	675,920	.192	.192	Nil	.1915	.1915	Nil	.1915	.1915	Nil	.1791	.180	+0.5	.1505	.151	+0.3	.179	.179	Nil

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TABLE NO. 23 (cont'd)

PADS - DIMENSIONAL CHECK

DISTORTION OF PADS FOLLOWING FATIGUE TEST

Test No.	Pad Ident.	Fatigue Cycles	LENGTH - INCHES									WIDTH - INCHES								
			End 1			Middle			End 2			End 1			Middle			End 2		
			Before	After	Diff %	Before	After	Diff %	Before	After	Diff %	Before	After	Diff %	Before	After	Diff %	Before	After	Diff %
34 Side A	Supplier E sample 2	595,810	.1915	.1925	+0.5	.1915	.192	+0.3	.1915	.192	+0.3	.180	.1805	+0.3	.150	.151	+0.7	.180	.1805	+0.3
34 Side B	Supplier E sample 2	595,810	.1915	+.1915	Nil	.1915	+.192	+0.3	.192	.193	+0.5	.180	+.180	Nil	.150	.151	+0.7	.180	.1805	+0.3
31 Side A	Supplier F sample 1	186,810	.178	.180	+1.1	.178	.180	+1.1	.178	.190	+1.1	.189	.194	+2.6	.168	bad	--	.189	.193	+2.1
31 Side B	Supplier F sample 1	186,810	.1775	.178	+0.3	.177	.178	+0.6	.177	.183	+3.4	.189	.190	+0.5	.168	.168	Nil	.189	.192	+1.6
32 Side A	Supplier E sample 1	646,160	.192	.193	+0.5	.192	.1925	+0.3	.192	.193	+0.5	.179	.1805	+0.8	.150	.151	+0.7	.179	.180	+0.6
32 Side B	Supplier E sample 1	646,160	.192	.192	Nil	.192	.1925	+0.3	.192	.193	+0.5	.179	.180	+0.6	.150	.151	+0.7	.179	.180	+0.6
22 Side A	Supplier A sample 1	88,700	.190	.190	Nil	.190	.190	Nil	.190	.1905	+0.3	.1915	.193	+0.8	.163	.163	Nil	.192	.193	+0.5
22 Side B	Supplier A sample 1	88,700	.190	.190	Nil	.190	.190	Nil	.190	.194	+2.1	.192	.195	+1.6	.163	.164	+0.6	.192	.1935	+0.8
23 Side A	Supplier A sample 1	79,080	.190	--	--	.190	.190	Nil	.190	.191	+0.5	.192	--	--	.163	--	--	.192	--	--
23 Side B	Supplier A sample 1	79,080	.190	.192	+1.1	.190	.191	+0.5	.190	--	--	.192	.195	+1.6	.163	--	--	.192	.195	+1.6

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TABLE NO. 23 (cont'd)

PADS - DIMENSIONAL CHECK

DISTORTION OF PADS FOLLOWING FATIGUE TEST

Test No.	Pad Ident.	Fatigue Cycles	LENGTH - INCHES									WIDTH - INCHES								
			End 1			Middle			End 2			End 1			Middle			End 2		
			Before	After	Diff %	Before	After	Diff %	Before	After	Diff %	Before	After	Diff %	Before	After	Diff %	Before	After	Diff %
29 Side A	Supplier D sample 4	653,510	.179	.180	+0.6	.1795	.180	+0.3	.179	.180	+0.6	.198	.198	Nil	.167	.167	Nil	.198	.198	Nil
29 Side B	Supplier D sample 4	653,510	.178	.1785	+0.3	.178	.179	+0.6	.1775	.179	+0.8	.1985	.1985	Nil	.169	.1685	-0.3	.1985	.1985	Nil

TABLE NO. 24

PADS - PROPERTY CHECK

THICKNESS, HARDNESS, AND WEIGHT CHANGE WITH FATIGUE LOADING

Pad Ident.	Test No.	Fatigue Cycles	Average Thickness			Average Hardness			Weight - Grams		
			Before	After	Diff %	Before	After	Diff %	Before	After	Diff %
Supplier A, sample No. 2	36	894,050	.203"	.203"	Nil	36.3D	38.3D	+5.5	158.7	158.9	+0.1
Supplier A, sample No. 2	36	894,050	.208"	.208"	Nil	36.7D	37.7D	+2.7	163.3	163.5	+0.1
Supplier D, sample No. 3	30	340,330	.257"	.266"	+2.3	82.3A	82.0A	-0.4	236.8	234.3	-1.1
Supplier D, sample No. 3	30	340,330	.257"	.261"	+1.6	82.3A	81.7A	-0.7	236.7	235.3	-0.6
Supplier A, sample No. 2	26	501,030	missing	.198"	--	35.3D	36.0D	+2.0	157.1	155.9	-0.8
Supplier A, sample No. 2	26	501,030	.196"	.192"	-2.0	35.0D	36.1D	+3.1	154.7	152.9	-1.2
Supplier D, sample No. 2	28	503,120	.196"	.200"	+2.0	80.6A	78.9A	-2.1	205.8	207.6	+0.9
Supplier D, sample No. 2	28	503,120	.197"	.1995"	+1.3	82.3A	79.2A	-3.8	207.3	207.9	Nil
Supplier E, sample No. 3	33	675,920	.196"	.199"	+1.5	83.7A	82.3A	-1.7	209.4	209.4	Nil
Supplier E, sample No. 3	33	675,920	.207"	.202"	-2.4	86.3A	85.7A	-0.7	212.5	212.3	-0.1

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TABLE NO. 24 (cont'd)

PADS - PROPERTY CHECK

THICKNESS, HARDNESS, AND WEIGHT CHANGE WITH FATIGUE LOADING

Pad Ident.	Test No.	Fatigue Cycles	Average Thickness			Average Hardness			Weight - Grams		
			Before	After	Diff %	Before	After	Diff %	Before	After	Diff %
Supplier E, sample No. 2	34	595,810	.191"	.194"	+1.5	83.9A	83.3A	-0.7	206.2	205.8	-0.2
Supplier E, sample No. 2	34	595,810	.190"	.192"	+1.1	82.1A	80.9A	-1.5	207.4	205.9	-0.7
Supplier F, sample No. 1	31	186,810	.244"	.252"	+3.3	70.7A	67.8A	-3.1	222.5	226.7	+1.9
Supplier F, sample No. 1	31	186,810	.237"	.237"	Nil	70.6A	69.8A	-1.1	212.8	211.4	-0.7
Supplier E, sample No. 1	32	646,160	.188"	.190"	+1.06	81.3A	80.2A	-1.4	182.1	181.4	-0.4
Supplier E, sample No. 1	32	646,160	.184"	.186"	+1.09	79.7A	80.2A	+0.6	178.3	179.5	+0.7
Supplier A, sample No. 1	22	88,700	.181"	.180"	+0.6	70.0A	60.0A	-14.3	180.7	181.0	+0.2
Supplier A, sample No. 1	22	88,700	.180"	.173"	-3.9	70.0A	68.3A	-2.4	180.1	179.0	-0.5

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TABLE NO. 24 (cont'd)

PADS - PROPERTY CHECK

THICKNESS, HARDNESS, AND WEIGHT CHANGE WITH FATIGUE LOADING

Pad Ident.	Test No.	Fatigue Cycles	Average Thickness			Average Hardness			Weight - Grams		
			Before	After	Diff %	Before	After	Diff %	Before	After	Diff %
Supplier A, sample No. 1	23	79,080	.184"	.185"	+0.6	70.0A	67.7A	-3.3	185.5	184.9	-0.3
Supplier A, sample No. 1	23	79,080	.185"	.191"	+3.2	70.0A	67.2A	-4.0	189.8	187.4	-1.3
Supplier D, sample No. 4	29	653,510	.189"	.190"	+0.6	94.0A	93.6A	-0.4	217.8	218.1	+0.1
Supplier D, sample No. 4	29	653,510	.191"	.192"	+0.6	94.0A	94.0A	Nil	220.4	220.6	+0.1

TABLE NO. 25

RELATIONSHIP BETWEEN FATIGUE TEST and PAD PHYSICAL PROPERTIES

(See Table No. 26)

Pad Identification	Tensile Strength (P.S.I.)	Abrasion Loss (Mg)	Static Stiffness M. lbs/in.	Deflection at 20 Kips (ins.)	No. of Fatigue Cycles	Pad * Condition Ranking
Supplier B, sample No. 1	1,555	Not Tested	1.322	0.0155	43,970	1
Supplier A, sample No. 1	1,490	250	1.176	0.0178	79,080	1
Supplier F, sample No. 1	Not Tested	421	0.724	0.0284	186,810	1
Supplier H, sample No. 2	1,650	310	6.400	0.0029	490,020	5
Supplier D, sample No. 3	1,540	591	0.630	0.0311	340,330	5
Supplier D, sample No. 2	1,950	420	4.324	0.0062	503,120	4
Supplier D, sample No. 4	1,863	322	22.857	0.0003	653,510	9
Supplier E, sample No. 2	930	472	6.154	0.0056	595,810	9

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TABLE NO. 25 (cont'd)

RELATIONSHIP BETWEEN FATIGUE TEST

and PAD PHYSICAL PROPERTIES

(See Table No. 26)

Pad Identification	Tensile Strength (P.S.I.)	Abrasion Loss (Mg)	Static Stiffness M. lbs/in.	Deflection at 20 Kips (ins.)	No. of Fatigue Cycles	Pad * Condition Ranking
Supplier E, sample No. 3	1,100	636	10.670	0.0020	675,920	8
Supplier E, sample No. 1	3,200	53	7.273	0.0032	646,160	9
Supplier A, sample No. 1	1,490	250	1.176	0.0178	1,028,170	8
Supplier A, sample No. 2	1,930	21	8.889	0.0061	894,050	9

TABLE NO. 26

PAD CONDITION AFTER FATIGUE TEST

Pad Condition Ranking	Description of Damage
1	Severe tearing and severe plastic flow
2	Moderate tearing and severe plastic flow
3	Slight tearing and severe plastic flow
4	Severe plastic flow and some tearing
5	Severe plastic flow
6	Moderate plastic flow
7	Slight plastic flow and abrasion
8	Moderate abrasion only
9	Slight abrasion
10	New

TABLE NO. 27

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
A	3	1	6	A	Field	992,390		Cracks in steel insert.
			7			1,736,250		Plastic flow in insulator post, abrasion of bearing plate.
			7			2,399,700		Crack from steel insert. Lug extends into post.
			7			3,736,250		Insulator failed.
							3,736,250	End of test.
A	3	2	6	A	Gauge	992,390		Cracks in steel insert.
			7			1,736,250		Slight abrasion of bearing plate.
			7			4,736,250		No change.
							4,736,250	End of test.
A	3	3	6	B	Gauge	992,390		Cracks in steel insert.
			6			1,028,170		No change.
							1,028,170	End of test.
A	3	4	6	B	Field	16,000		Steel insert lug cracked.
			6			36,080		Crack extends into insulator post.
			6			64,750		Crack extends into steel bearing plate.
			6			992,390		Insulator failed.
							992,390	End of test.
A	3	5	6	B	Field	1,400		Steel insert lug cracked.
			6			35,780		Insulator failed.
							35,780	End of test.

(continued on next page)

TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
A	4	1	7	A	Field	708,080		Plastic flow in post.
			7			4,708,080		No change.
			8			6,453,580		No change.
							6,453,580	End of test.
A	4	2	7	B	Field	708,080		Slight abrasion of bearing plate.
			7			4,708,080		No change.
			8			6,453,580		Plastic insulator cracked under steel insert.
							6,453,580	End of test.
A	5	1	10	A	Field	307,050		Steel insert lug cracked.
			10			1,541,170		Insulator failed.
							1,541,170	End of test.
A	5	2	10	B	Field	1,541,170		No defects.
							1,541,170	End of test.
A	5	3	10	A	Gauge	453,000		Steel insert lug cracked.
			10			1,342,750		Crack increased in length
			10			3,972,750		No change.
							3,972,750	End of test.
A	5	4	10	B	Gauge	3,972,750		No defects.
							3,972,750	End of test.
A	5	5	10	A	Field	145,950		Insulator post broken.
							145,950	End of test.

(continued on next page)

TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
A	5	6	10	B	Field	145,950	145,950	Insulator post broken. End of test.
A	5	7	10	B	Field	2,285,630	2,285,630	No defects. End of test.
A	5	8	10	A	Field	2,285,630	2,285,630	No defects. End of test.
A	5	9	11	A	Field	1,258,640	1,258,640	No defects. End of test.
A	5	10	11	A	Gauge	1,258,640	1,258,640	No defects. End of test.
A	5	11	11	B	Field	1,258,640	1,258,640	No defects. End of test.
A	5	12	11	B	Gauge	1,258,640	1,258,640	No defects. End of test.
S	2	18	15 16 17	A	Field	358,430 3,083,950 4,249,770	4,249,770	No defects. No defects. Insulator failed. End of test.
S	2	19	15 16 17	A	Gauge	358,430 3,083,950 4,249,770	4,249,770	No defects. No defects. Insulator failed. End of test.

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TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
S	2	20	15	B	Field	74,090		Separation of plastic insulator and steel insert.
			15			138,670		Plastic insulator cracked.
							138,670	End of test.
S	2	21	15	B	Gauge	358,430		No defects.
							358,430	End of test.
S	2	22	16	B	Field	2,000,000		Separation of plastic and metal insert.
							2,000,000	End of test.
S	2	23	16	B	Gauge	3,083,950		No defects.
			17			3,594,390		No defects.
							3,594,390	End of test.
S	3	24	17	B	Field	304,000		Cracked lug on steel insert.
						500,440		Total failure.
							500,440	End of test.
S	1	7	12	A	Field	4,000		No defects.
							4,000	End of test.
S	1	8	12	A	Gauge	4,000		No defects.
							4,000	End of test.
S	1	14	12	B	Field	110		Insulator failed.
							110	End of test.

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TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
S	1	15	12	B	Gauge	4,000	4,000	No defects. End of test.
S	1	16	13	B	Field	320	320	Insulator failed. End of test.
S	1	17	14	B	Field	570	570	Insulator failed. End of test.
S	1	10	14	B	Field	3,000	3,000	Insulator failed. End of test.
A	5	13	18	A	Field	816,400	816,400	No defects. End of test.
A	5	14	18	A	Gauge	816,400	816,400	No defects. End of test.
A	5	15	18	B	Field	816,400	816,400	Corner of plastic insulator broken. End of test.
A	5	16	18	B	Gauge	816,400	816,400	No defects. End of test.
A	5	17	19	A	Field	1,069,840	1,069,840	Slight abrasion on plastic insulator. End of test.
A	5	18	19	A	Gauge	1,069,840	1,069,840	No defects. End of test.
A	5	19	19	B	Field	1,069,840	1,069,840	Slight abrasion on plastic insulator. End of test.

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TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab	Lab Test	Test	Rail	Number of	Total Number of	
Supplier	Sample	No.	No.	Side	Side	Cycles	Cycles	Remarks
A	5	20	19	B	Gauge	1,069,840		No defects.
							1,069,840	End of test.
A	5	21	20	A	Field	464,540		Steel insert cracked.
			20			648,250		Plastic insulator is cracked and moving out from under steel insert.
			20			673,270		Plastic insulator almost out from under steel insert.
							673,270	End of test.
A	5	22	20	A	Gauge	673,270		No defects.
							673,270	End of test.
A	5	22	20	B	Field	673,270		No defects.
							673,270	End of test.
A	5	23	20	B	Gauge	673,270		No defects.
							673,270	End of test.
A	5	24	21	A	Gauge	189,230		No defects.
							189,230	End of test.
A	5	25	21	A	Field	62,420		Steel insert lug cracked.
			21			189,230		No change.
							189,230	End of test.
A	5	26	21	B	Field	78,280		Steel insert lug cracked.
			21			189,230		Total failure.
							189,230	End of test.
A	5	27	21	B	Gauge	189,230		No defects.
							189,230	End of test.

(continued on next page)

TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
A	5	28	23 23	A	Field	54,780 79,080	 79,080	Steel insert cracked. Severe abrasion on plastic insulator. End of test.
A	5	29	23	A	Gauge	79,080	 79,080	No defects. End of test.
A	5	30	23	B	Field	79,080	 79,080	No defects. End of test.
A	5	31	23	B	Gauge	79,080	 79,080	No defects. End of test.
A	5	32	25	A	Field	490,000	 490,000	No defects. End of test.
A	5	33	25	A	Gauge	490,000	 490,000	No defects. End of test.
A	5	34	25	B	Field	490,000	 490,000	No defects. End of test.
A	5	35	25	B	Gauge	490,000	 490,000	No defects. End of test.
A	5	36	26	A	Field	288,930 501,030	 501,030	Steel insert log cracked. No change. End of test.
A	5	37	26	A	Gauge	501,030	 501,030	No defects. End of test.

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TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
A	5	38	26 26	B	Field	33,440 501,030	 501,030	Broken lug on steel insert. No change. End of test.
A	5	39	26	B	Gauge	501,030	 501,030	No defects. End of test.
A	5	40	28	A	Field	503,120	 503,120	No defects. End of test.
A	5	41	28	A	Gauge	503,120	 503,120	No defects. End of test.
A	5	42	28 28 28	B	Field	28,980 379,230 503,120	 503,120	Steel insert lug cracked. Steel insert lug broken off. No change. End of test.
A	5	43	28	B	Gauge	503,120	 503,120	No defects. End of test.
A	5	44	29	A	Field	680 653,510	 653,510	Steel insert lug cracked. No change. End of test.
A	5	45	29	A	Gauge	653,510	 653,510	No defects. End of test.
A	5	46	29 29	B	Field	680 653,510	 653,510	Steel insert lub cracked. No change. End of test.

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TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
A	5	47	29	B	Gauge	653,510	653,510	No defects. End of test.
A	5	48	30 30	A	Field	37,510 340,330	340,330	Steel insert lug cracked. No change. End of test.
A	5	49	30	A	Gauge	340,330	340,330	No defects. End of test.
A	5	50	30 30	B	Field	37,510 340,330	340,330	Steel insert lug cracked. Steel insert post cracked. End of test.
A	5	51	30	B	Gauge	340,330	340,330	No defects. End of test.
A	5	52	31 31	A	Field	127,660 186,810	186,810	Steel insert lug cracked. No change. End of test.
A	5	53	31	A	Gauge	186,810	186,810	No defects. End of test.
A	5	54	31 31	B	Field	127,660 186,810	186,810	Steel insert lug cracked. No change. End of test.
A	5	55	31	B	Gauge	186,810	186,810	No defects. End of test.
A	5	56	32	A	Field	646,160	646,160	Broken lug on steel insert. End of test.

(continued on next page)

TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
A	5	57	32	A	Gauge	646,160	646,160	No defects. End of test.
A	5	58	32	B	Field	646,160	646,160	No defects. End of test.
A	5	59	32	B	Gauge	646,160	646,160	No defects. End of test.
A	5	60	33	A	Field	675,920	675,920	Broken lug on steel insert. End of test.
A	5	61	33	A	Gauge	675,920	675,920	No defects. End of test.
A	5	62	33	B	Field	675,920	675,920	No defects. End of test.
A	5	63	33	B	Gauge	675,920	675,920	No defects. End of test.
A	5	64	34	A	Field	595,810	595,810	No defects. End of test.
A	5	65	34	A	Gauge	595,810	595,810	No defects. End of test.
A	5	66	34 34	B	Field	340,510 595,810	595,810	Broken lug on steel insert. No change. End of test.

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TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
A	5	67	34	B	Gauge	595,810	595,810	No defects. End of test.
A	7	1	35	A	Field	536,810	536,810	No defects. End of test.
A	7	2	35	A	Gauge	536,810	536,810	No defects. End of test.
A	7	3	35	B	Field	536,810	536,810	No defects. End of test.
A	7	4	35	B	Gauge	536,810	536,810	No defects. End of test.
N	1	1	36	A	Field	894,050	894,050	No defects. End of test.
N	1	2	36	A	Gauge	894,050	894,050	No defects. End of test.
N	1	3	36	B	Field	894,050	894,050	No defects. End of test.
N	1	4	36	B	Gauge	894,050	894,050	No defects. End of test.
N	2	1	38	A	Field	503,000	503,000	No defects. End of test.
N	2	2	38	A	Gauge	503,000	503,000	No defects. End of test.
N	2	3	38	B	Field	503,000	503,000	No defects. End of test.

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TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab	Lab Test	Test	Rail	Number of	Total Number of	
Supplier	Sample	No.	No.	Side	Side	Cycles	Cycles	Remarks
N	2	4	38	B	Gauge	503,000		No defects.
							503,000	End of test.
O	1	1	39	A	Field	36,220		Broken lug on insulator.
			39			596,090		Insulator cracked along length of post.
							596,090	End of test.
O	1	2	39	B	Field	36,220		Broken lug on insulator.
			39			596,090		Insulator cracked along length of post.
							596,090	End of test.
A	5	68	39	A	Gauge	596,090		No defects.
							596,090	End of test.
A	5	69	39	B	Gauge	596,090		No defects.
							596,090	End of test.
O	2	1	40	A	Field	10		Insulator lug cracked.
			40			155,780		Crack extends into middle of post.
			40			164,330		Lug broken off.
							164,330	End of test.
O	3	1	40	B	Field	164,330		No defects.
			41			296,160		Both lugs and post broken off.
			41			692,770		No change.
							692,770	End of test.

(continued on next page)

TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
O	4	1	41	A	Field	131,830		Crack extends from lug along radius between bearing plate and post.
			41			528,440		No change.
							528,440	End of test.
O	5	1	42	A	Field	50		Insulator lug cracked.
			42			540,170		Insulator post cracked. Lugs broken.
			42			540,170		No change.
							540,170	End of test.
A	5	70	40	A	Gauge	164,330		No defects.
			41			528,440		No defects.
			42			540,170		No defects.
							1,232,940	End of test.
A	5	71	40	B	Gauge	164,330		No defects.
			41			528,440		No defects.
			42			540,170		No defects.
							1,232,940	End of test.
A	5	72	42	B	Field	540,170		No defects.
							540,170	End of test.
J	4	1	46	A	Field	260,000		Separation between post and steel plates.
						574,280		Insulation material under steel bearing plate cracked in two places.
							574,280	End of test.

(continued on next page)

TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab	Lab Test	Test	Rail	Number of	Total Number of	
Supplier	Sample	No.	No.	Side	Side	Cycles	Cycles	Remarks
J	4	2	46	B	Field	260,000		Insulating material has worn away from post - no electrical ground.
						574,280		No change.
							574,280	End of test.
Q	1	1	47	A	Field	790		Lugs on insulators curling up around tie shoulders.
						528,850		Broken lug and cracked post, indent in bearing area.
							528,850	End of test.
Q	1	2	47	B	Field	790		Lugs on insulators curling up around tie shoulders.
						76,620		Insulator post crushed.
						578,850		3/4 post worn away. Indent in bearing plate.
							528,850	End of test.
A	6	1	48	A	Field	2,000,000		Post cracked from lug into bearing plate area.
							2,000,000	End of test.
A	6	2	48	A	Gauge	2,000,000		No defects.
							2,000,000	End of test.
A	6	3	48	B	Field	2,000,000		Post crushed and broken off. No electrical ground.
							2,000,000	End of test.
A	6	4	48	B	Gauge	2,000,000		No defects.
							2,000,000	End of test.

(continued on next page)

TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
R	1	1	49	A	Field	2,000,000	2,000,000	Post crushed in the middle. End of test.
R	1	2	49	A	Gauge	2,000,000	2,000,000	No defects. End of test.
R	1	3	49	B	Field	506,840 2,000,000	2,000,000	Insulator slightly bulged. Post crushed. No electrical ground. End of test.
R	1	4	49	B	Gauge	2,000,000	2,000,000	No defects. End of test.
R	2	1	50	A	Field	170	170	Post cracked and crack extends into bearing area. End of test.
R	2	2	50	A	Guage	170	170	Insulator bulges between nylon insert and post. End of test.
R	2	3	50	B	Field	170	170	Insulator broke into several pieces. End of test.
R	2	4	50	B	Gauge	170	170	Post cracked and crack runs the length of insulator. End of test.
R	3	1	51	A	Field	960,960	960,960	No defects. End of test.
R	3	2	51	A	Gauge	960,960	960,960	No defects. End of test.

(continued on next page)

TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
R	3	3	51	B	Field	788,040		Post bulging out from tie shoulders. Abrasion wear in post.
						815,110		Post breaking apart.
						960,960		Insulator disintegrated.
							960,960	End of test.
R	3	4	51	B	Gauge	960,960		No defects.
							960,960	End of test.
R	4	1	52	A	Field	1,605,810		Post cracked.
							1,605,810	End of test.
R	4	2	52	A	Gauge	1,605,810		No defects.
							1,605,810	End of test.
R	4	3	52	B	Field	391,890		Post being crushed.
						1,605,810		Post broken-off.
							1,605,810	End of test.
R	4	4	52	B	Gauge	1,605,810		No defects.
							1,605,810	End of test.
R	5	1	53	A	Field	560		Post cracked.
						809,900		Post being crushed.
						2,000,000		Insulator distorted and abraded.
							2,000,000	End of test.
R	5	2	53	A	Gauge	2,000,000		No defects.
							2,000,000	End of test.

(continued on next page)

TABLE NO. 27 (cont'd)

INSULATORS - FATIGUE TESTS

Insulator Identification		Lab No.	Lab Test No.	Test Side	Rail Side	Number of Cycles	Total Number of Cycles	Remarks
Supplier	Sample							
R	5	3	53	B	Field	560 809,900 2,000,000	2,000,000	Post cracked. Post being crushed. Insulator distorted and abraded. End of test.
R	5	4	53	B	Gauge	2,000,000	2,000,000	No defects. End of test.
P	1	5	3	A	Field	940,640	940,640	Distortion of post and section broken-off. End of test.
P	1	6	3	A	Gauge	940,640	940,640	No defects. End of test.
P	1	9	4	A	Field	316,470	316,470	Distortion of post section broken-off. End of test.
P	1	10	4	A	Gauge	316,470	316,470	No defects. End of test.
P	1	11	2	B	Field	1,652,870	1,652,870	Distortion and plastic flow of post. End of test.
P	1	12	2	B	Gauge	1,652,870	1,652,870	No defects. End of test.

TABLE NO. 28

INSULATORS - SUMMARY OF FATIGUE TESTS

Insulator Supplier	Sample No.	Number Tested	Average Number of Test Cycles	Number Developing Defects	Average Number of Cycles to 1st Defect
A	3	5	2,105,768	5	598,914
A	4	2	6,453,580	2	708,080
A	5	72	759,803	23	304,943
A	6	4	2,000,000	2	2,000,000
A	7	4	536,810	Nil	--
S	1	7	2,285	3	1,143
N	1	4	894,050	Nil	--
N	2	4	503,000	Nil	--
O	1	2	596,090	2	36,220
O	2	1	164,330	1	10
O	3	1	692,770	1	296,160
O	4	1	528,440	1	131,830
O	5	1	540,170	1	50
J	4	2	574,280	2	260,000
Q	1	2	528,850	2	790
R	1	4	2,000,000	2	1,253,420
R	2	4	170	4	170
R	3	4	960,960	1	788,040

(continued on next page)

TABLE NO. 28 (cont'd)

INSULATORS - SUMMARY OF FATIGUE TESTS

Insulator Supplier	Sample No.	Number Tested	Average Number of Test Cycles	Number Developing Defects	Average Number of Cycles to 1st Defect
R	4	4	1,605,810	2	998,850
R	5	4	2,000,000	2	560
S	2	6	2,098,505	4	2,643,408
S	3	1	500,440	1	304,000
P	1	6	969,993	3	969,993

PADS - LOAD/DEFLECTION TESTS

Symbol	Supplier	Sample No.	Lab No.
.	L	1	1
x	L	1	2
o	L	1	3

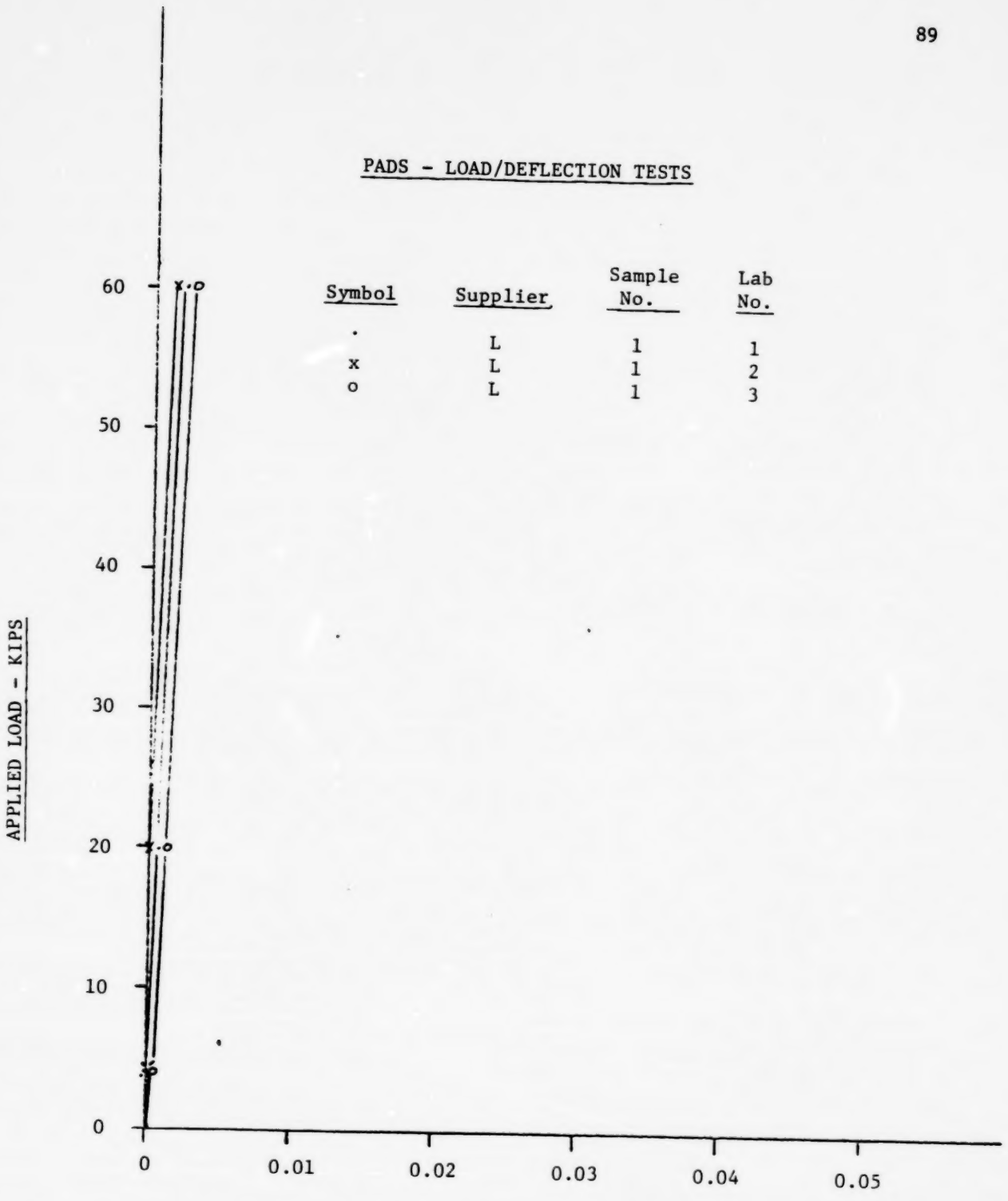


FIGURE NO. 1

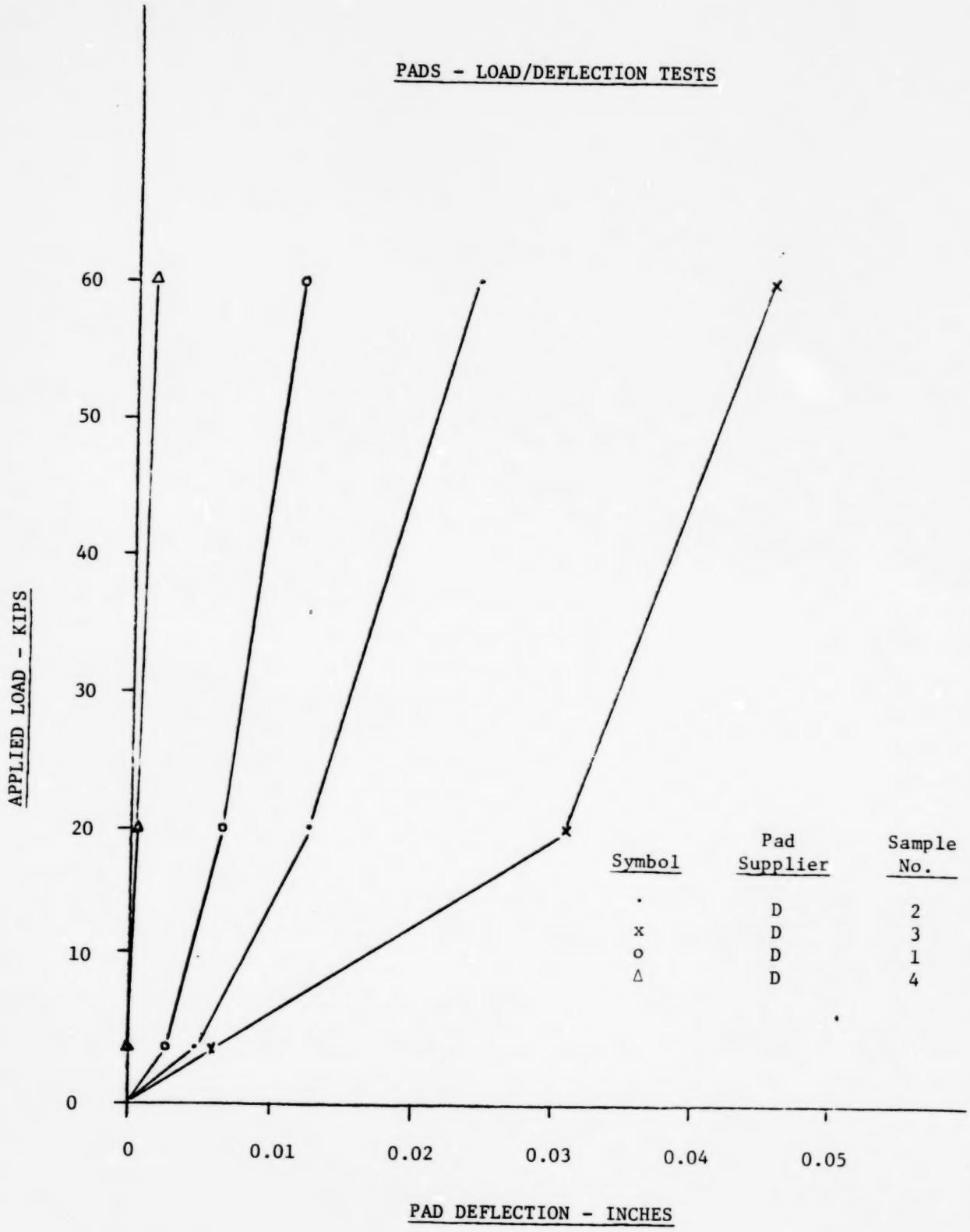

PADS - LOAD/DEFLECTION TESTS
APPLIED LOAD - KIPS
60
50
40
30
20
10
0
0
0.01
0.02
0.03
0.04
0.05
PAD DEFLECTION - INCHES
Symbol
Pad Supplier
Sample No.
. D 2
x D 3
o D 1
Δ D 4

FIGURE NO. 2

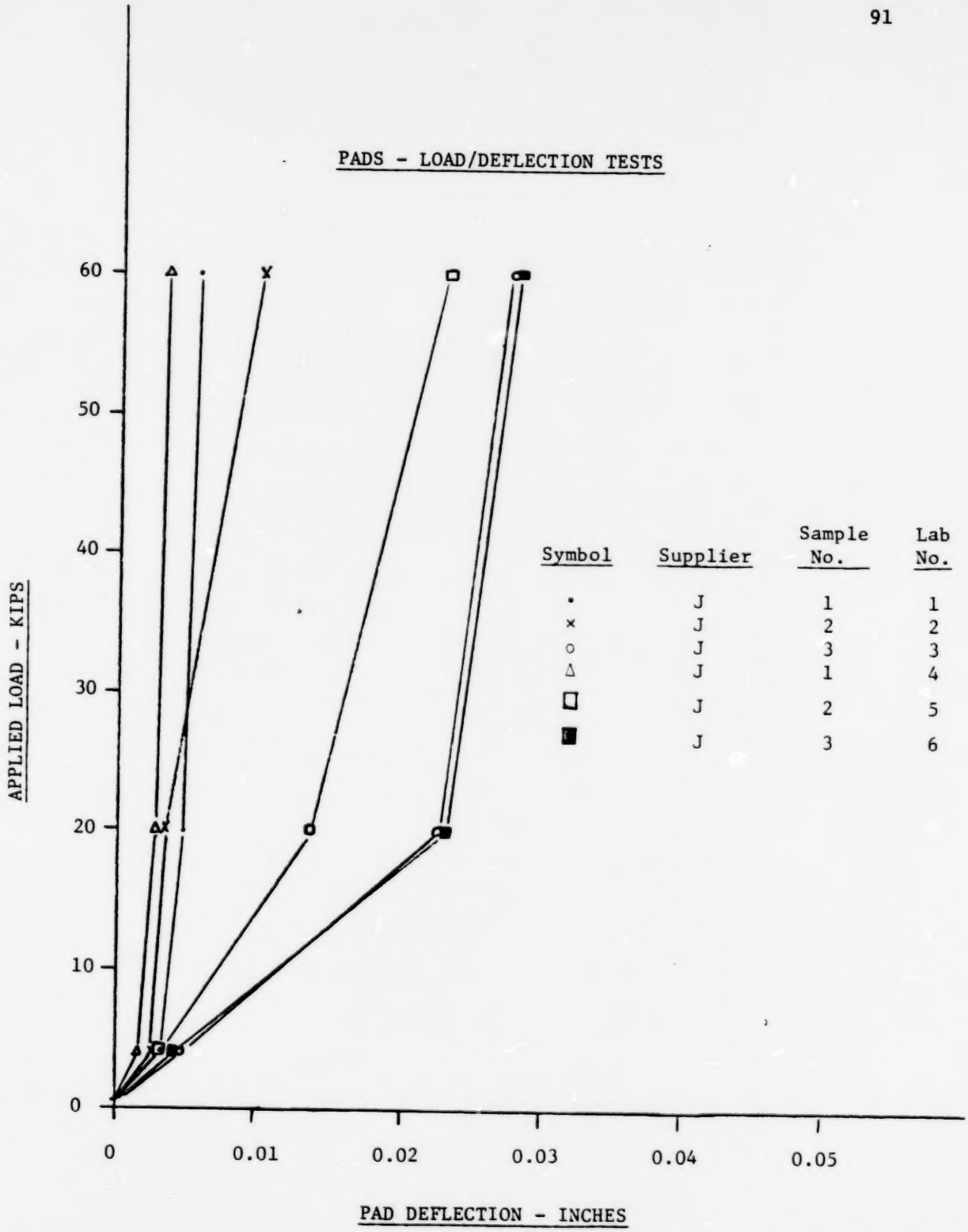

PADS - LOAD/DEFLECTION TESTS
APPLIED LOAD - KIPS
60
50
40
30
20
10
0
0
0.01
0.02
0.03
0.04
0.05
PAD DEFLECTION - INCHES
Symbol
Supplier
Sample No.
Lab No.
• J 1 1
× J 2 2
○ J 3 3
△ J 1 4
□ J 2 5
■ J 3 6

FIGURE NO. 3

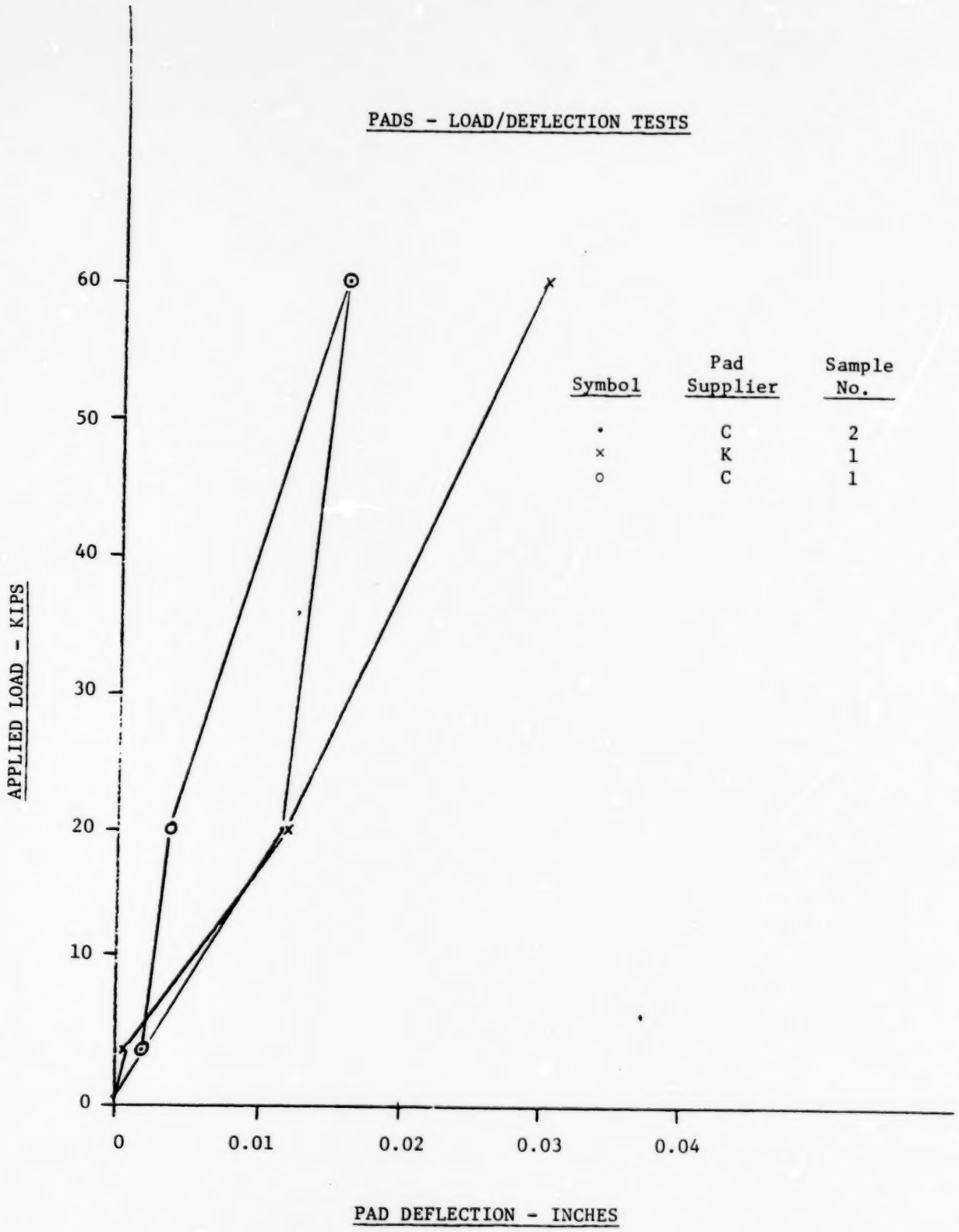

PADS - LOAD/DEFLECTION TESTS
APPLIED LOAD - KIPS
60
50
40
30
20
10
0
0
0.01
0.02
0.03
0.04
PAD DEFLECTION - INCHES
Symbol
Pad Supplier
Sample No.
• C 2
× K 1
o C 1

FIGURE NO. 4

PADS - LOAD/DEFLECTION TESTS

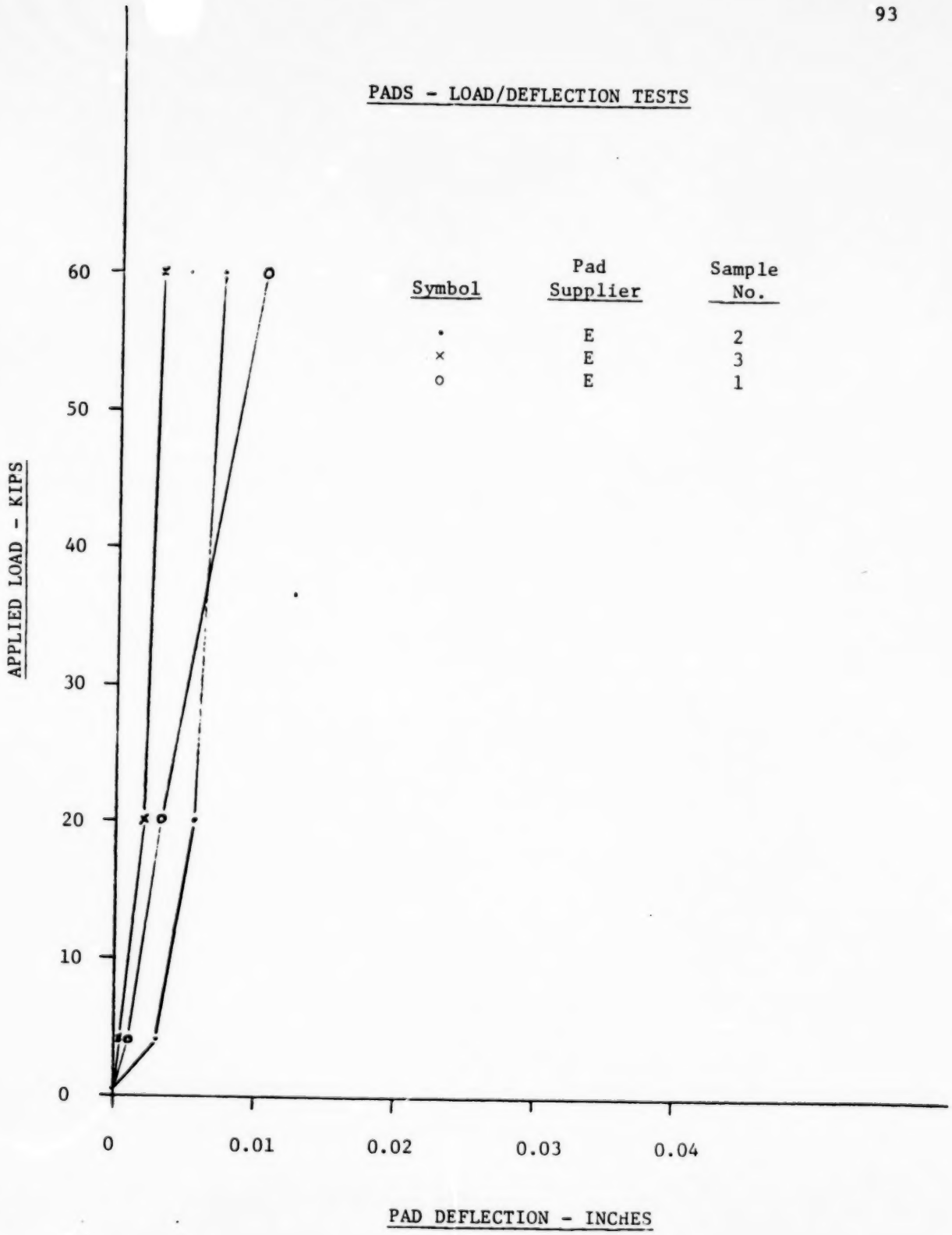


FIGURE NO. 5

PADS - LOAD/DEFLECTION TESTS

Symbol	Pad Supplier	Sample No.	Lab No.
•	I	2	2
×	I	2	4

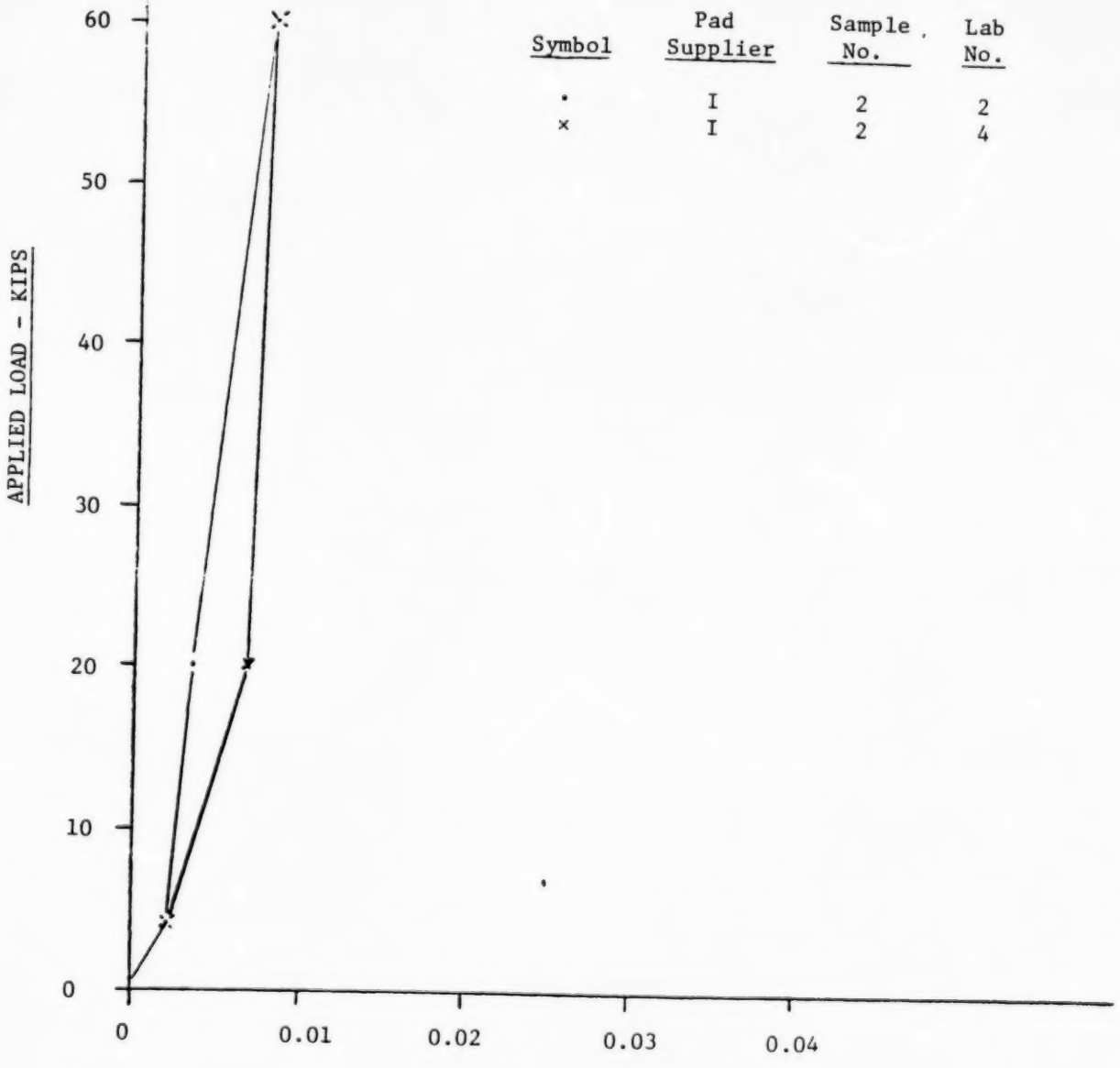


FIGURE NO. 6

PADS - LOAD/DEFLECTION TESTS

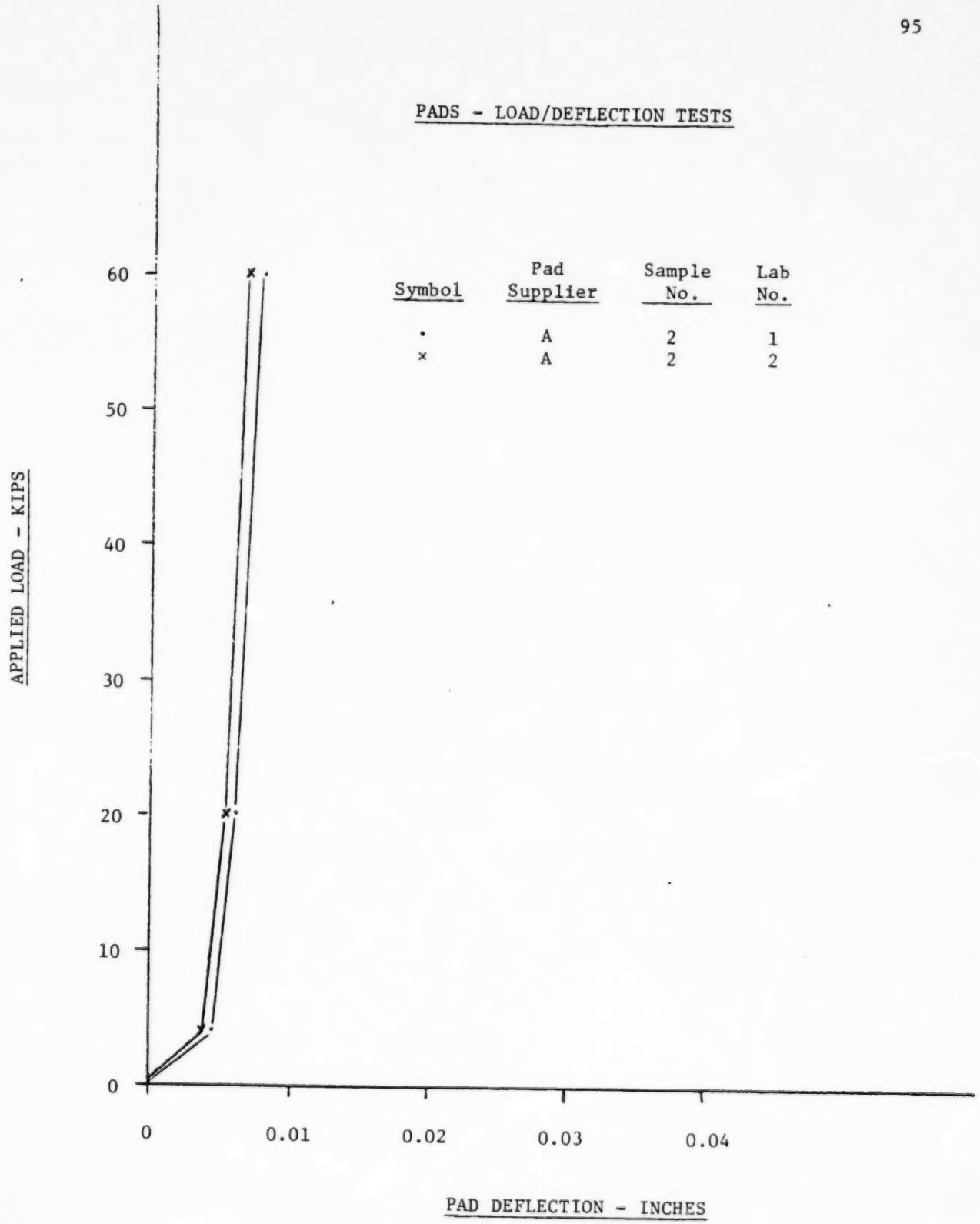


FIGURE NO. 7

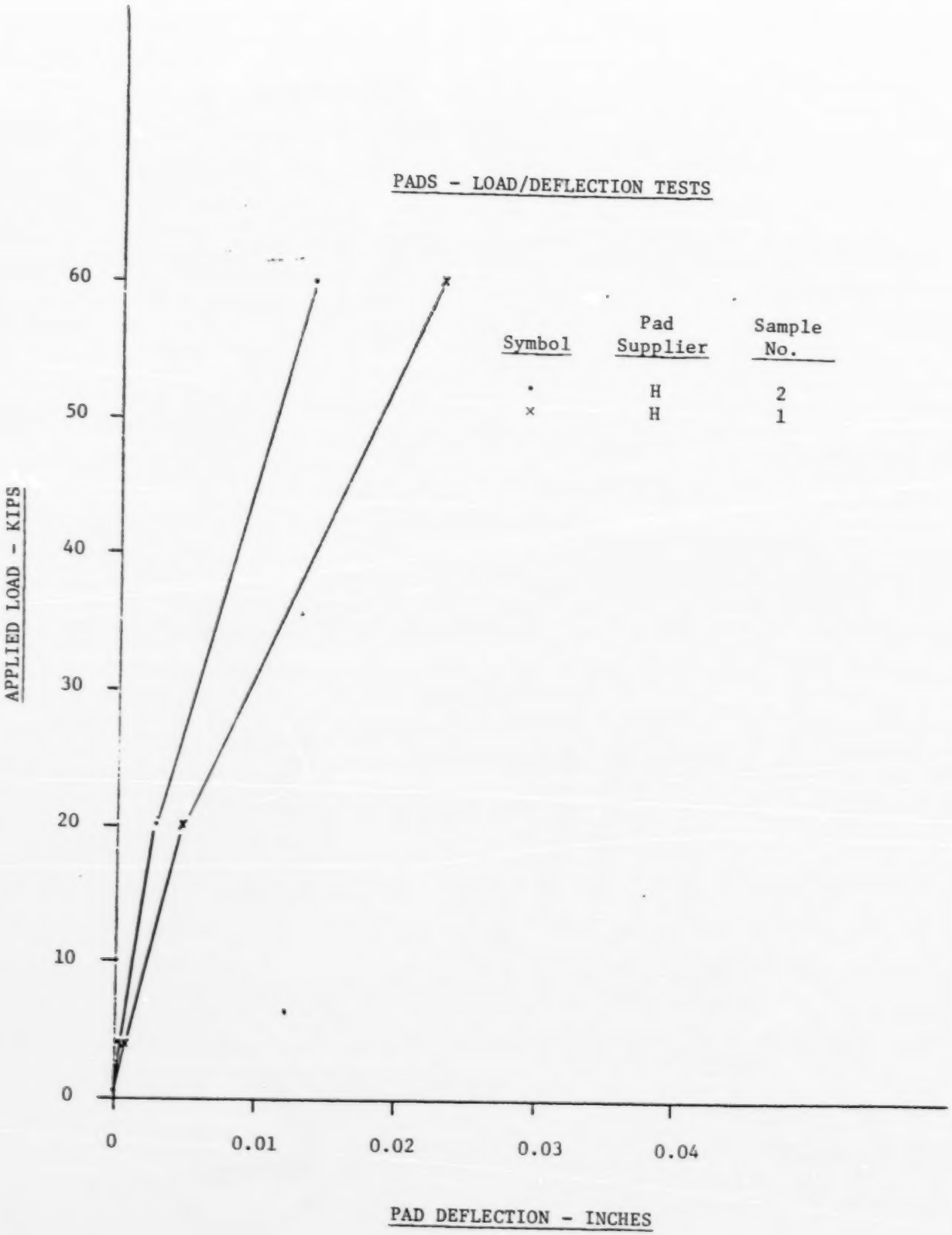

PADS - LOAD/DEFLECTION TESTS
Symbol
Pad Supplier
Sample No.
• H 2
× H 1
APPLIED LOAD - KIPS
60
50
40
30
20
10
0
0
0.01
0.02
0.03
0.04
PAD DEFLECTION - INCHES

FIGURE NO. 8

PADS - LOAD/DEFLECTION TESTS

Symbol	Pad Supplier	Sample No.	Lab No.
•	I	1	1
×	I	1	2

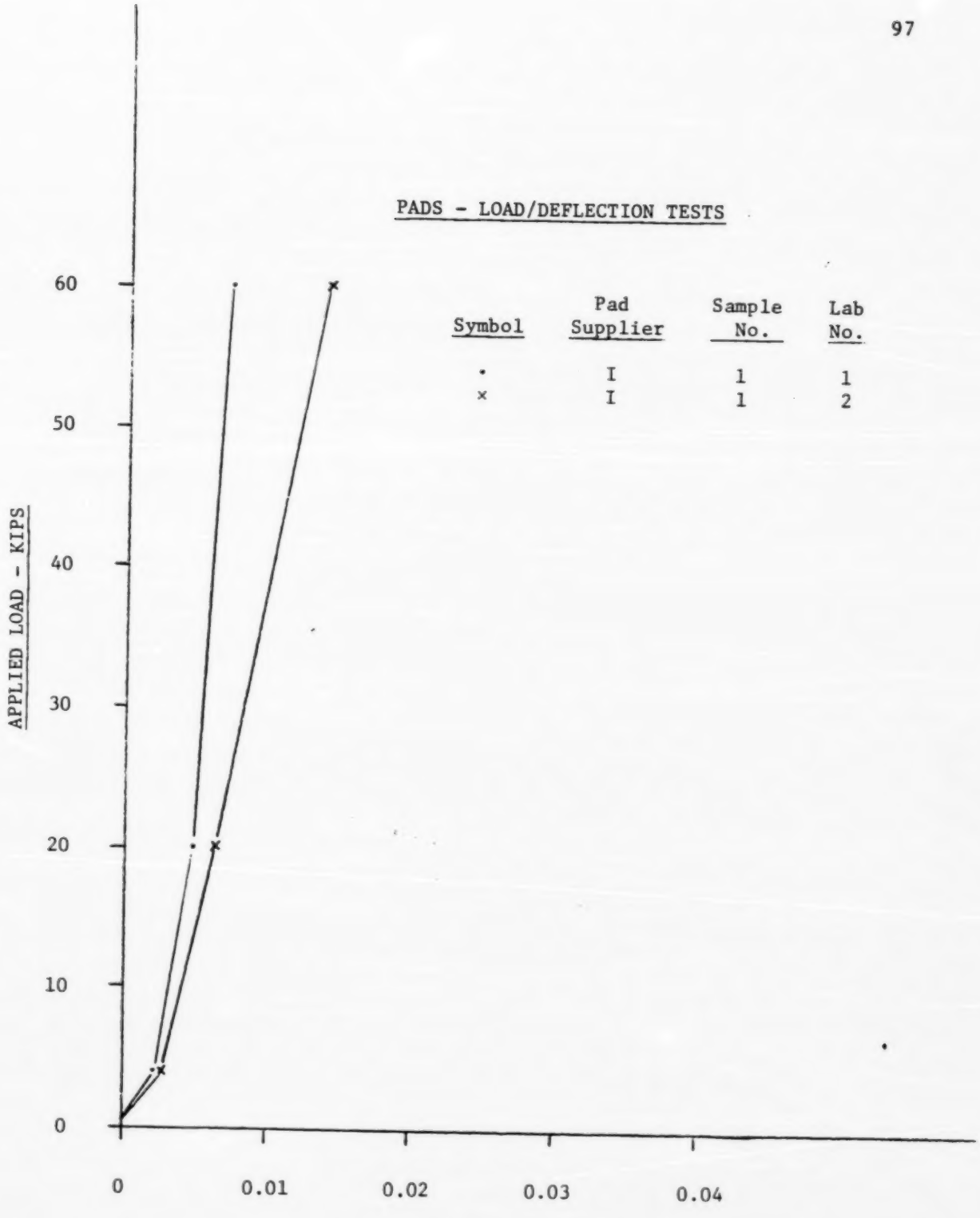
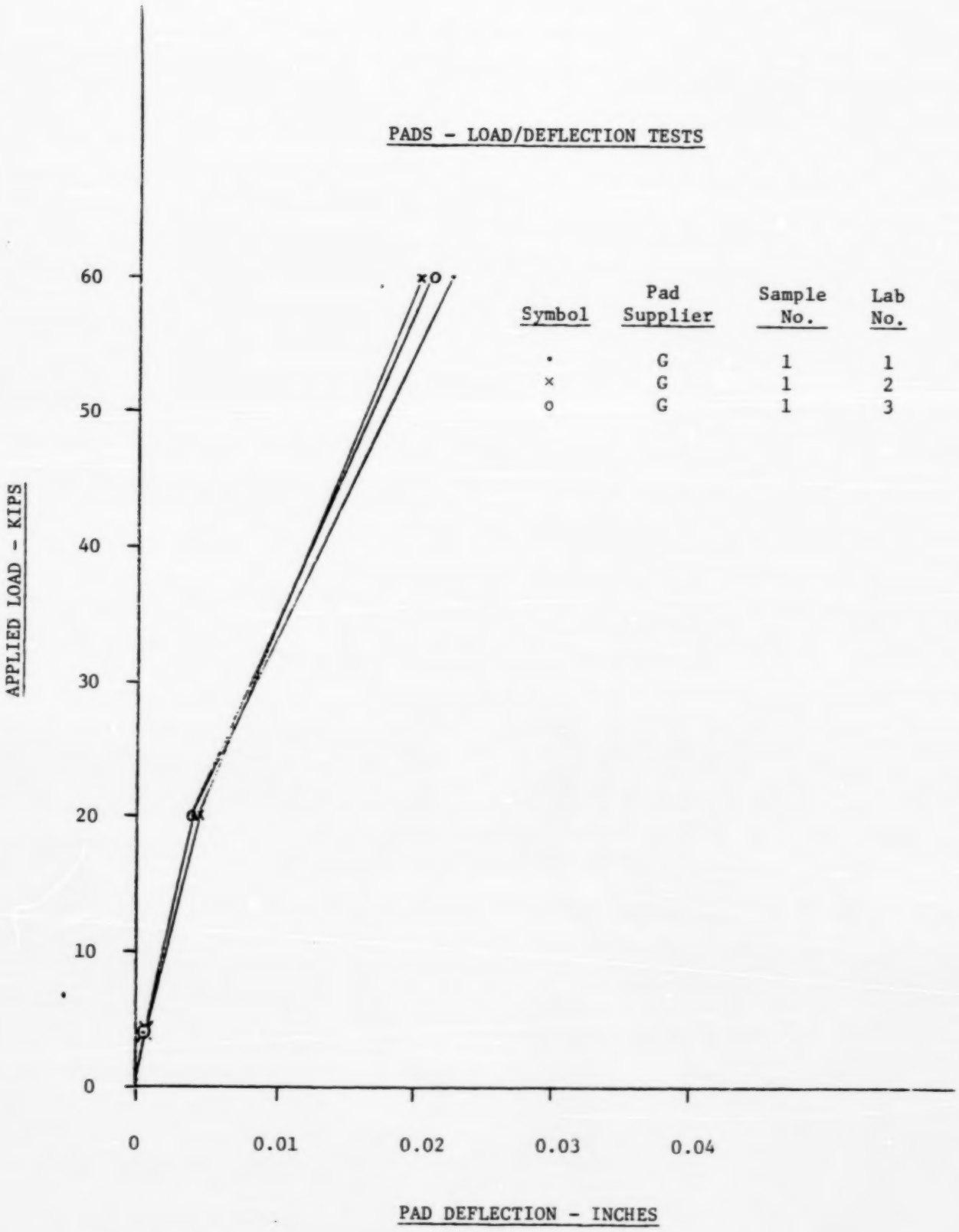


FIGURE NO. 9

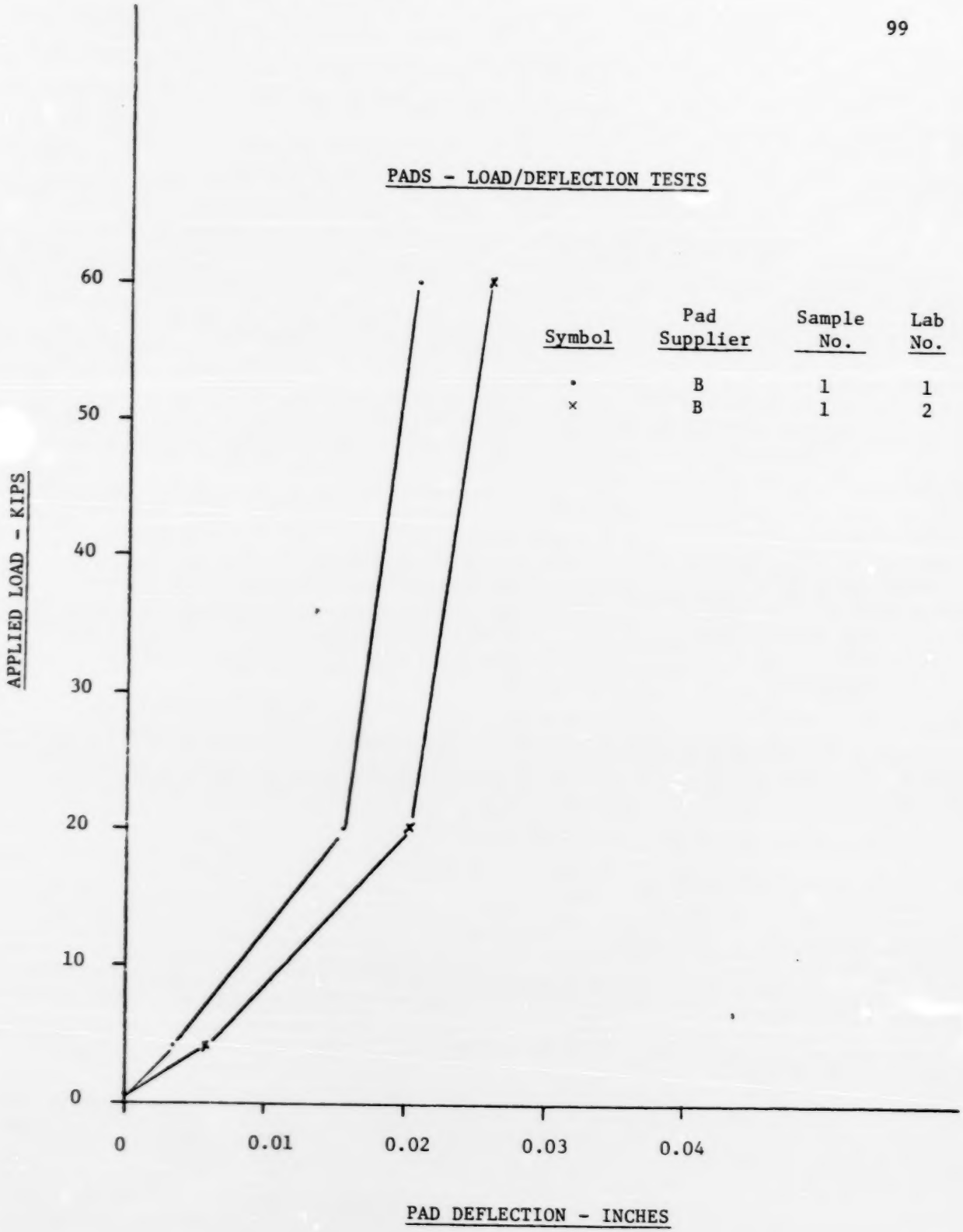
PADS - LOAD/DEFLECTION TESTS



Symbol	Pad Supplier	Sample No.	Lab No.
•	G	1	1
×	G	1	2
o	G	1	3

FIGURE NO. 10

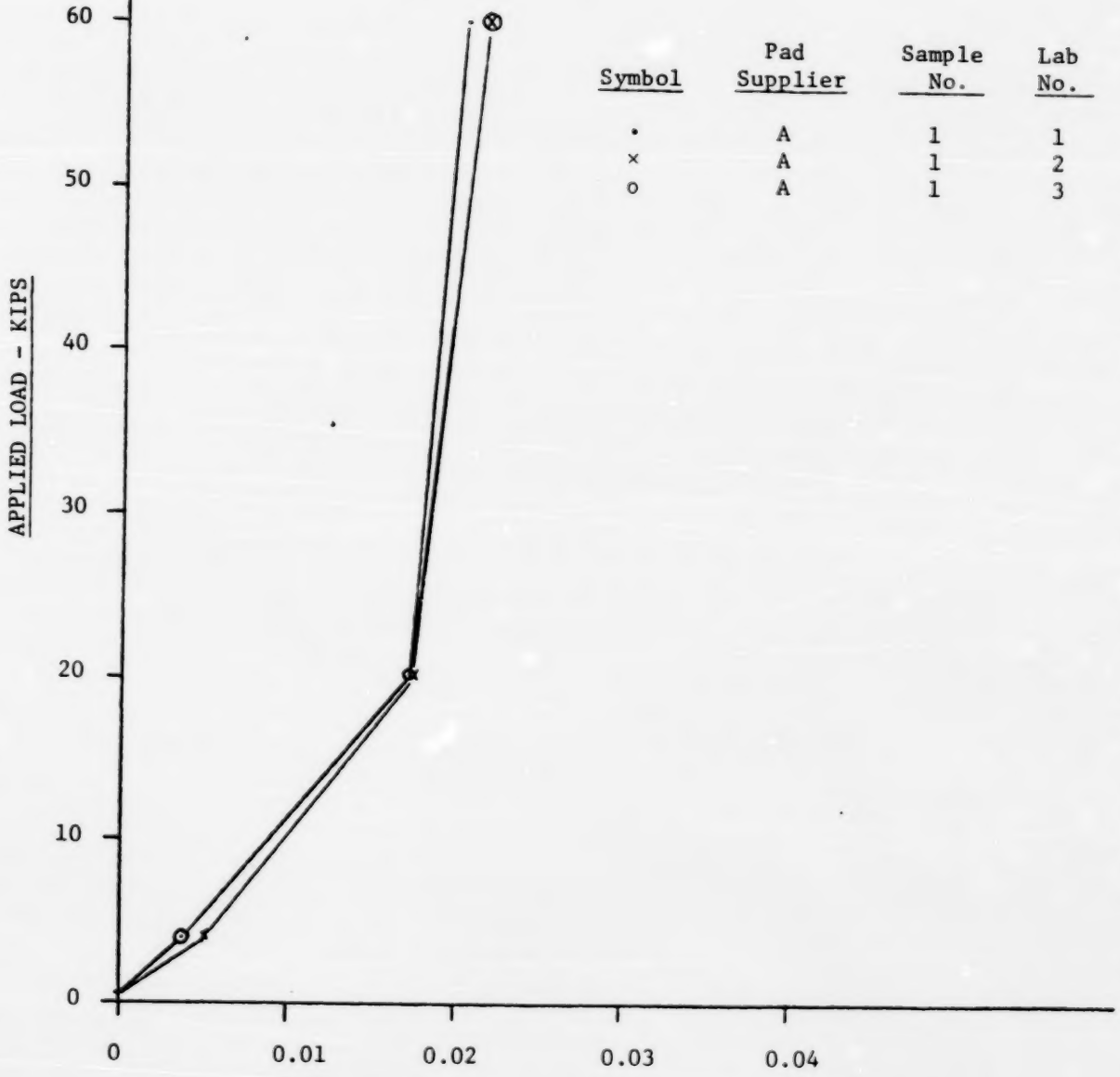
PADS - LOAD/DEFLECTION TESTS



Symbol	Pad Supplier	Sample No.	Lab No.
•	B	1	1
×	B	1	2

FIGURE NO. 11

PADS - LOAD/DEFLECTION TESTS



Symbol	Pad Supplier	Sample No.	Lab No.
•	A	1	1
×	A	1	2
o	A	1	3

FIGURE NO. 12

PADS - LOAD/DEFLECTION TESTS

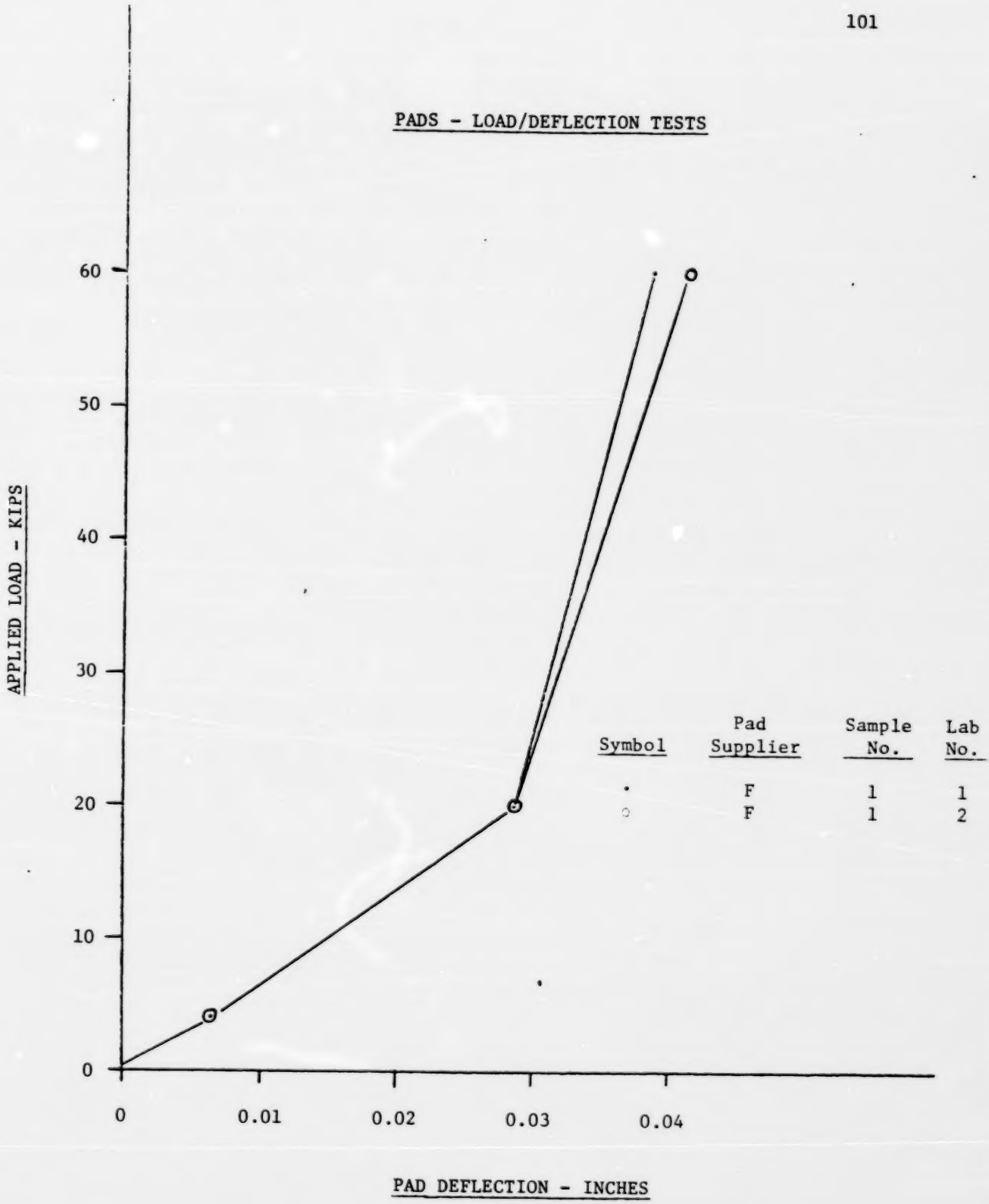
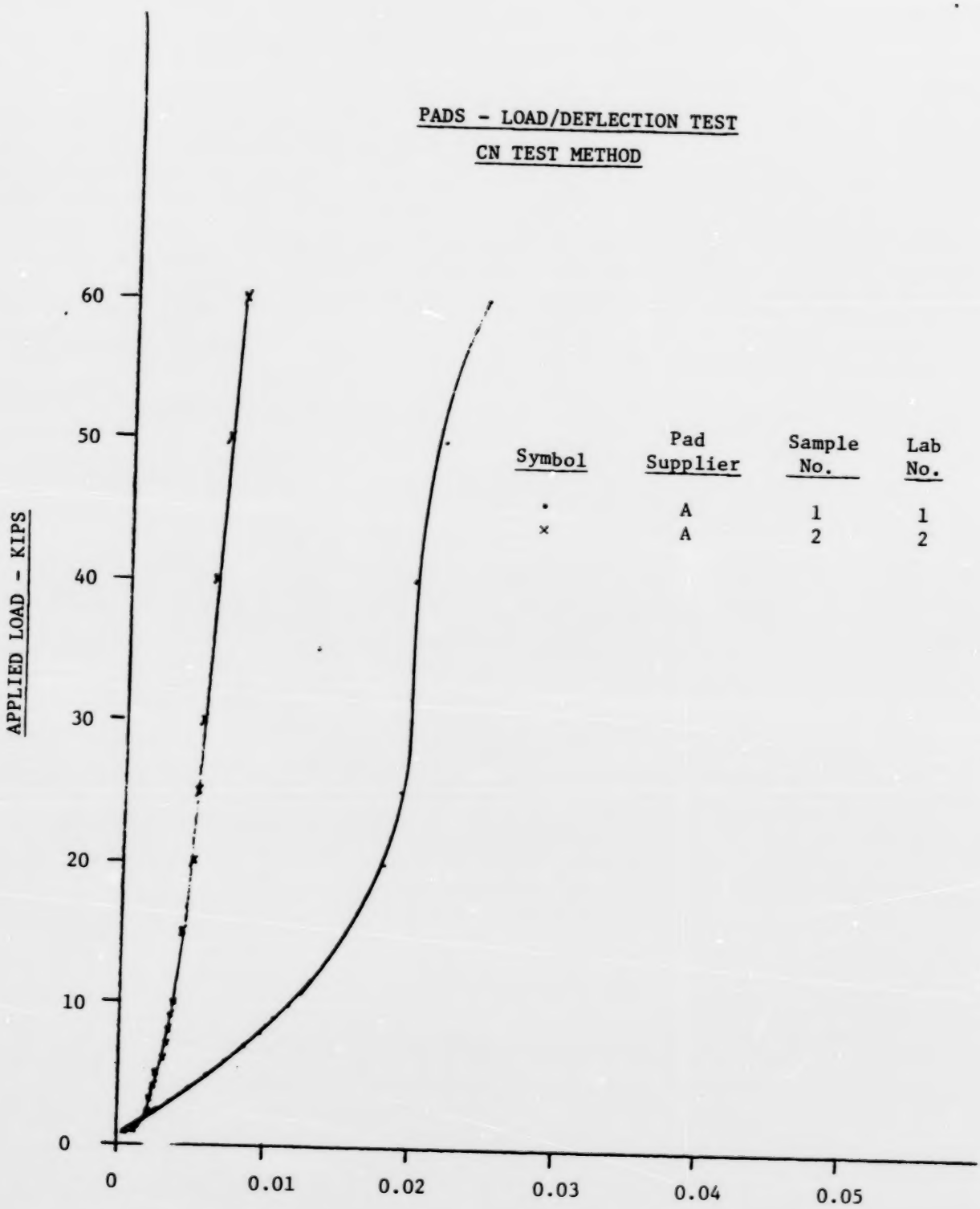


FIGURE NO. 13

PADS - LOAD/DEFLECTION TEST

CN TEST METHOD



Symbol	Pad Supplier	Sample No.	Lab No.
•	A	1	1
×	A	2	2

FIGURE NO. 14

PADS - LOAD/DEFLECTION TESTS

SUPPLIER D'S METHOD

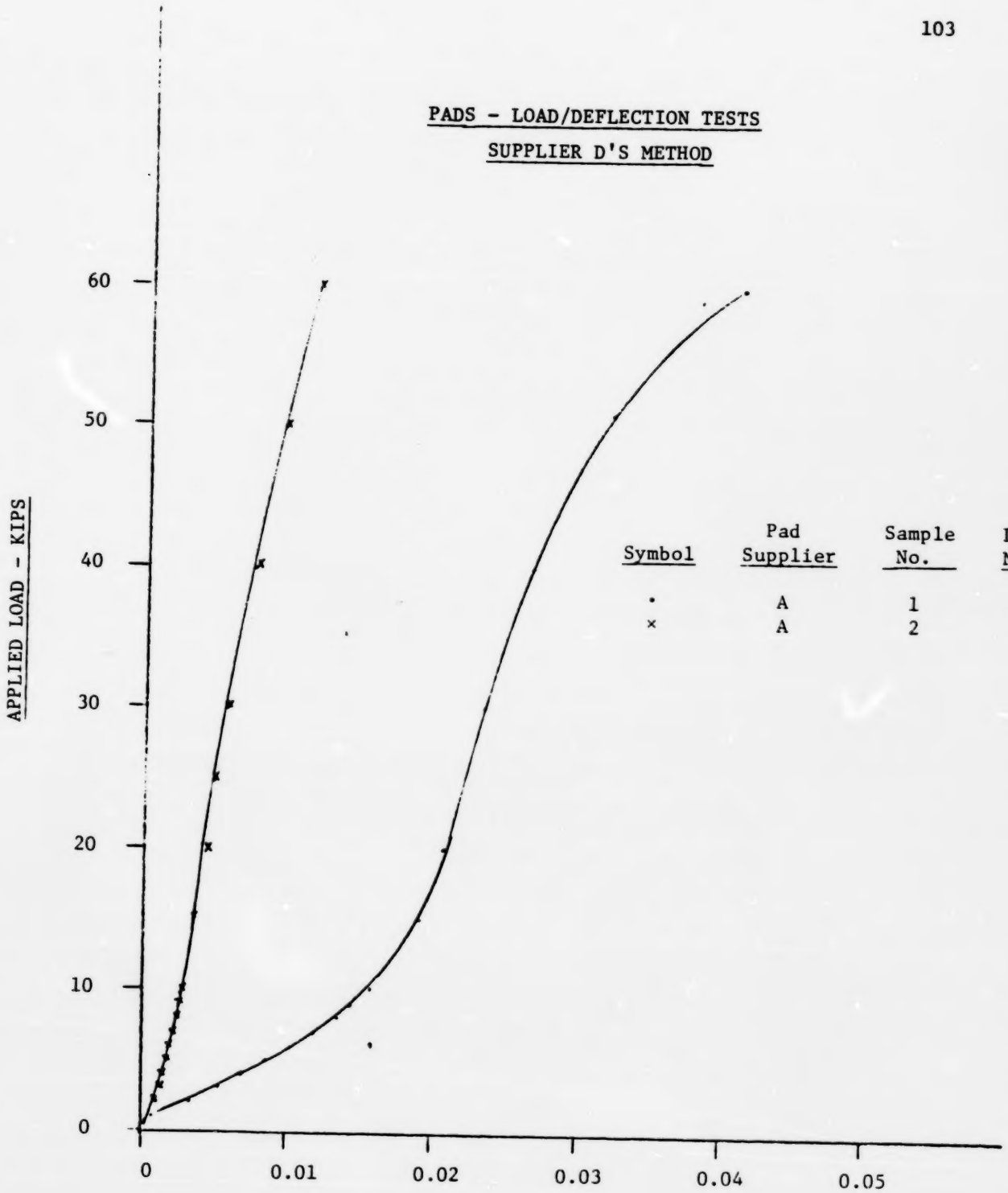


FIGURE NO. 15

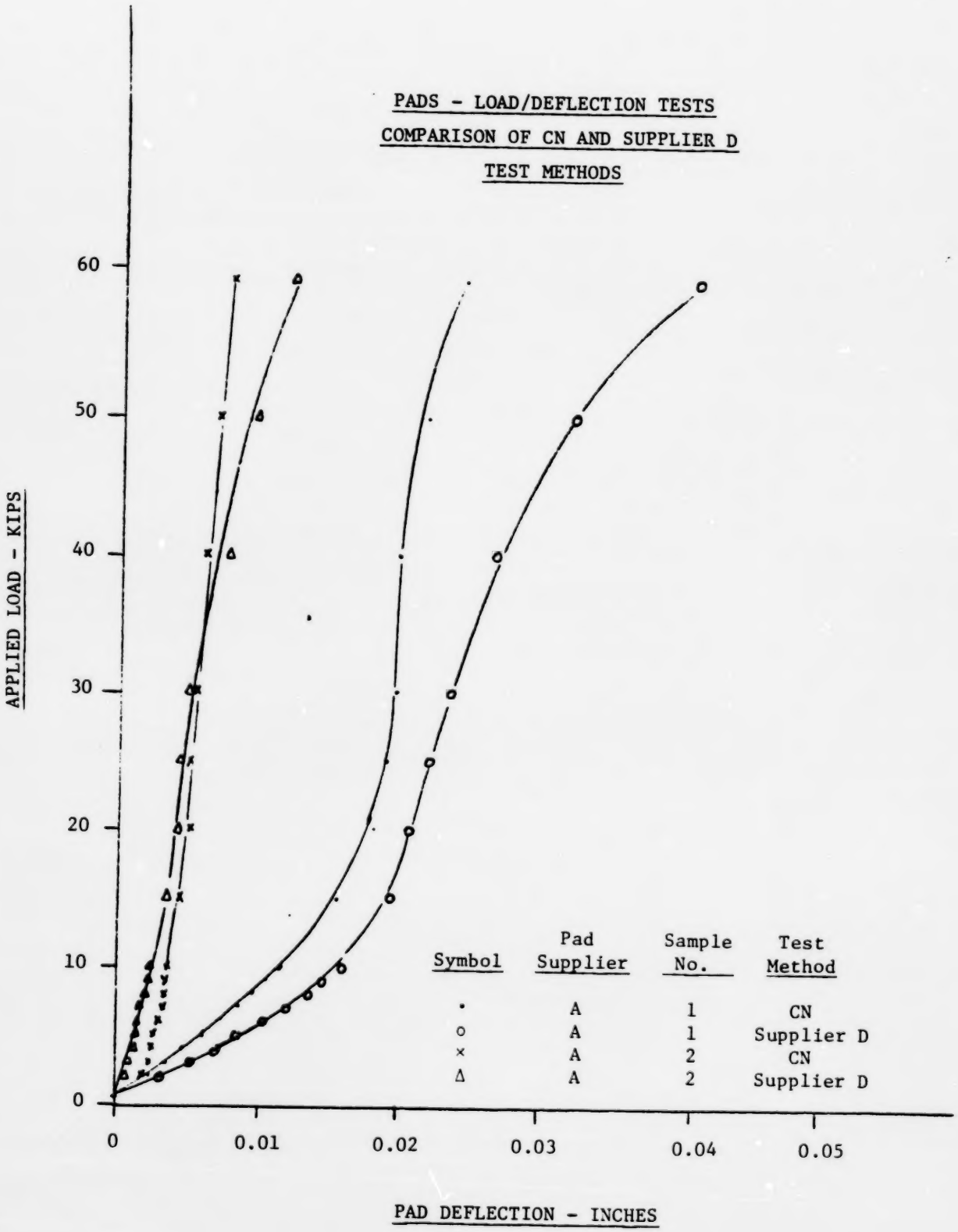

PADS - LOAD/DEFLECTION TESTS
COMPARISON OF CN AND SUPPLIER D
TEST METHODS
APPLIED LOAD - KIPS
60
50
40
30
20
10
0
0
0.01
0.02
0.03
0.04
0.05
PAD DEFLECTION - INCHES
Symbol
Pad Supplier
Sample No.
Test Method
• A 1 CN
o A 1 Supplier D
× A 2 CN
Δ A 2 Supplier D

FIGURE NO. 16

PADS - LOAD/DEFLECTION TESTS

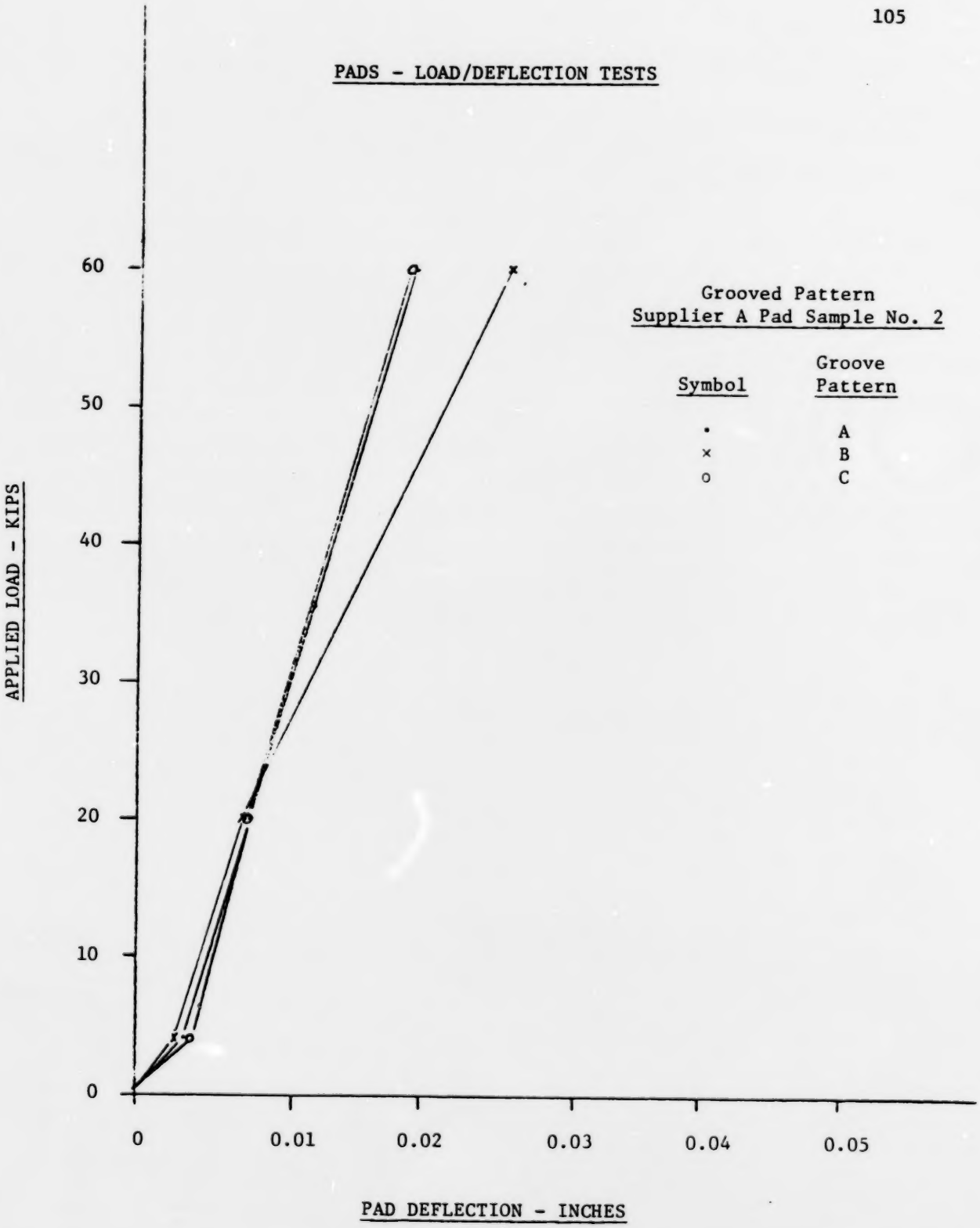
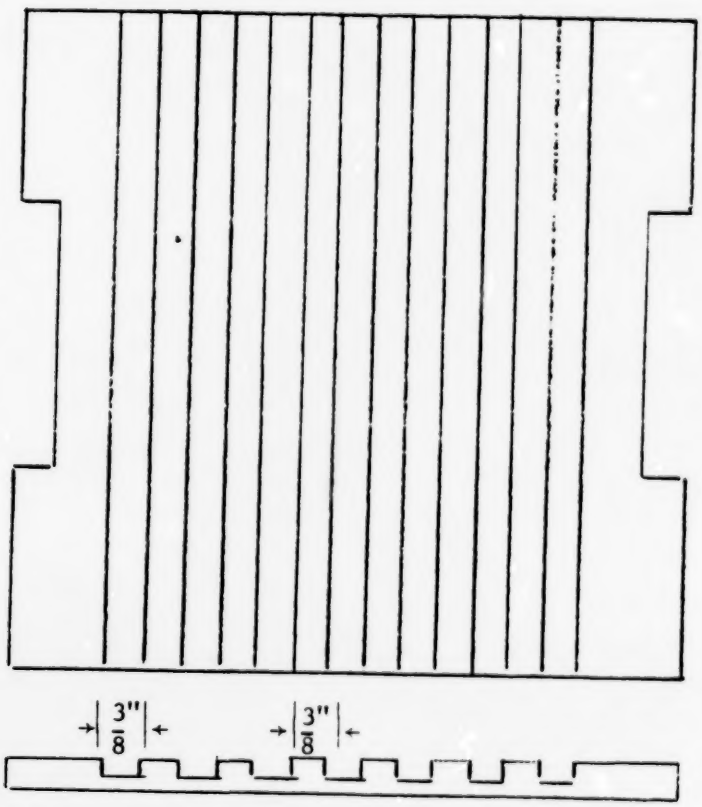


FIGURE NO. 17

CONFIGURATION OF GROOVES MACHINED

INTO SUPPLIER A'S, SAMPLE NO. 2 PAD

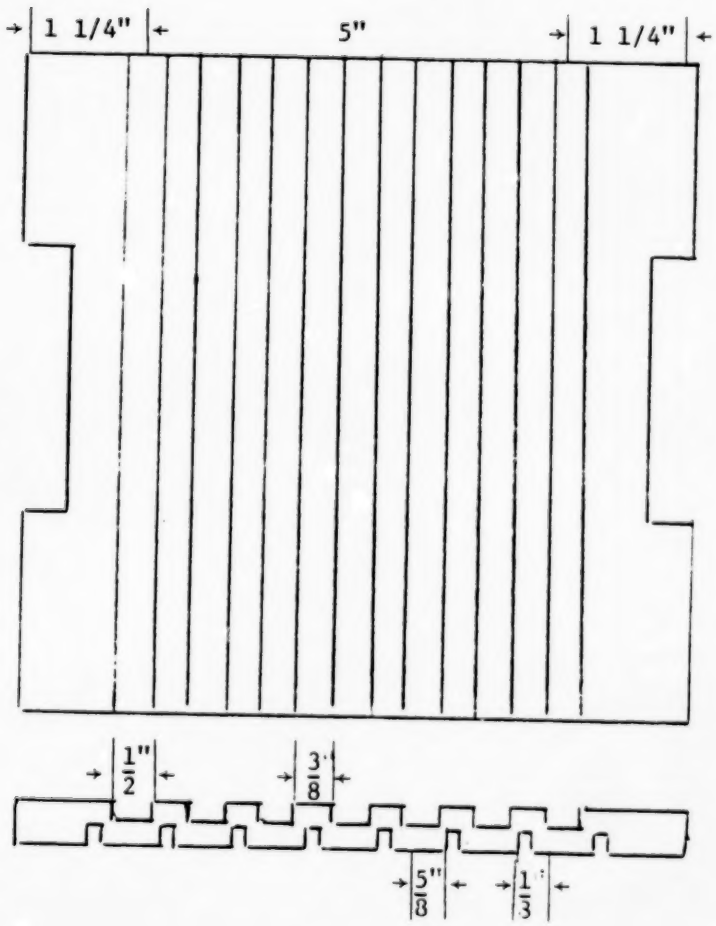


GROOVE PATTERN 'A'

FIGURE NO. 18

CONFIGURATION OF GROOVES MACHINED

INTO SUPPLIER A'S SAMPLE NO. 2 PAD

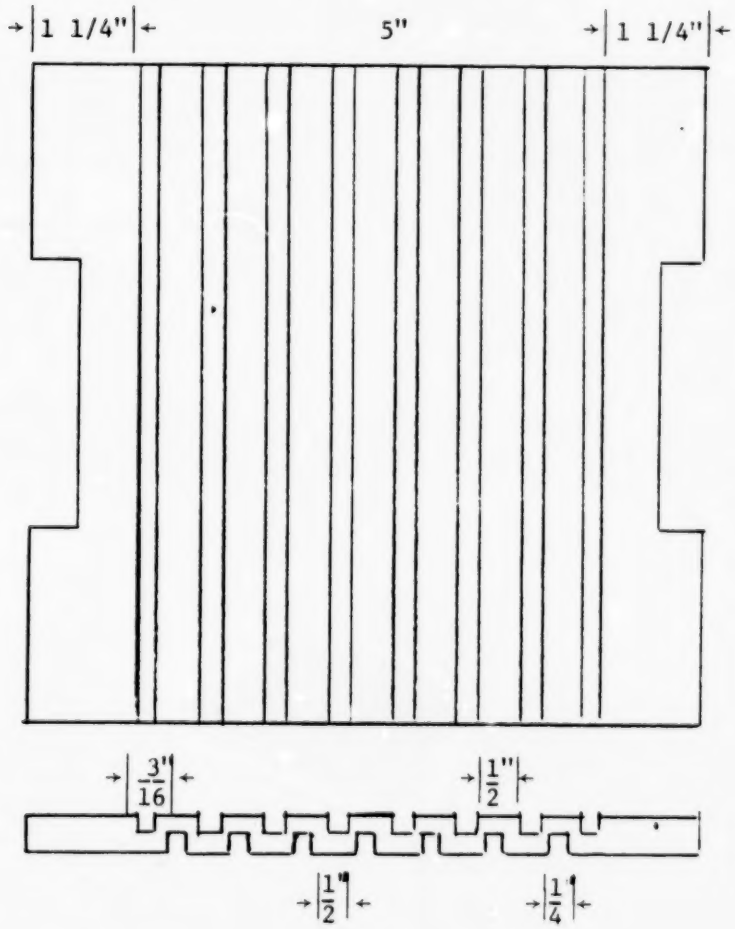


GROOVE PATTERN 'B'

FIGURE NO. 19

CONFIGURATION OF GROOVES MACHINED

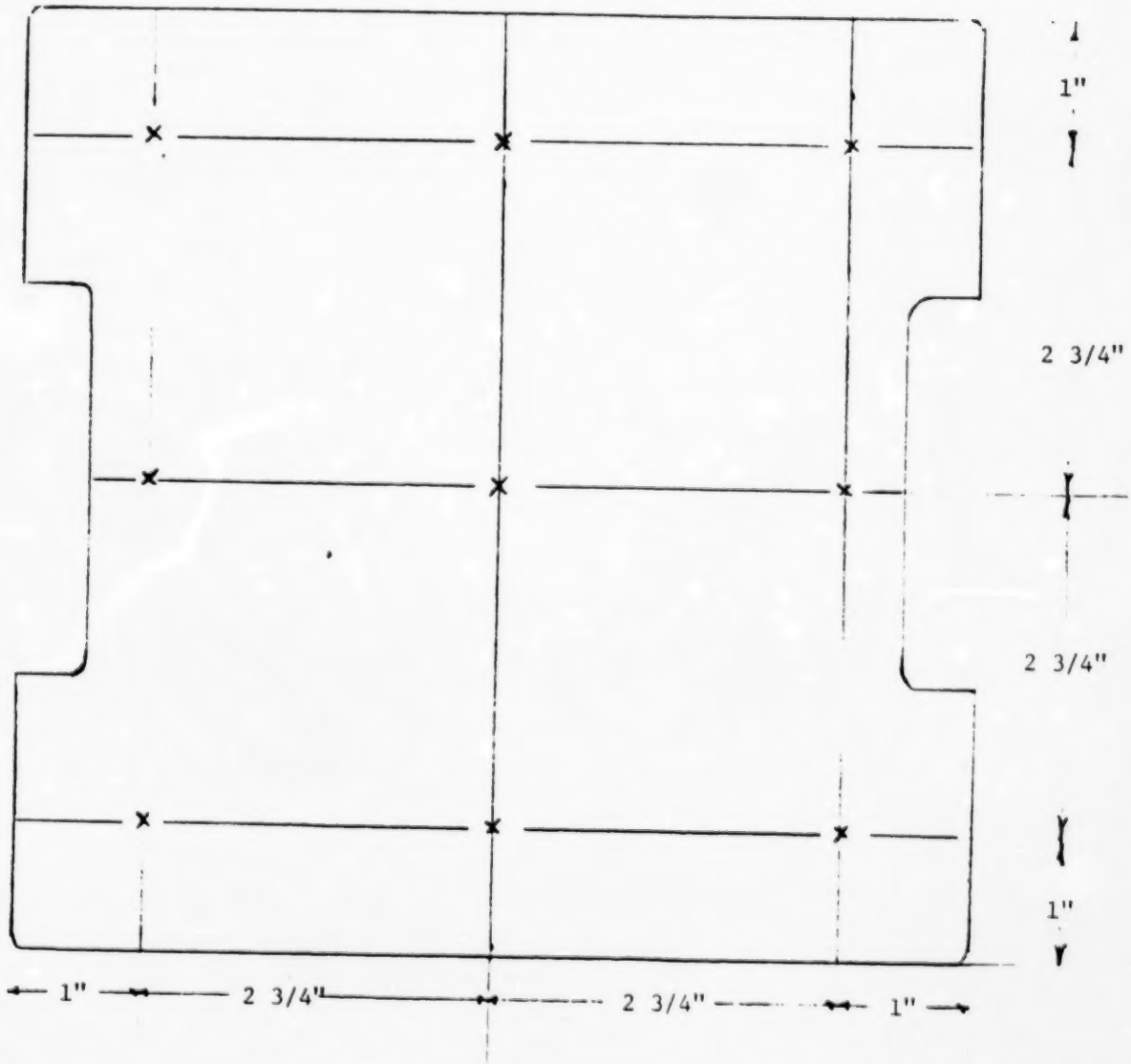
INTO SUPPLIER A'S SAMPLE NO. 2 PAD



GROOVE PATTERN 'C'

FIGURE NO. 20

PAD PROFILE



NOTE:- VERTICAL LINES DENOTE LENGTH MEASUREMENTS
HORIZONTAL LINES DENOTE WIDTH MEASUREMENTS
X MARKS THE THICKNESS AND HARDNESS MEASUREMENTS

FIGURE NO. 21

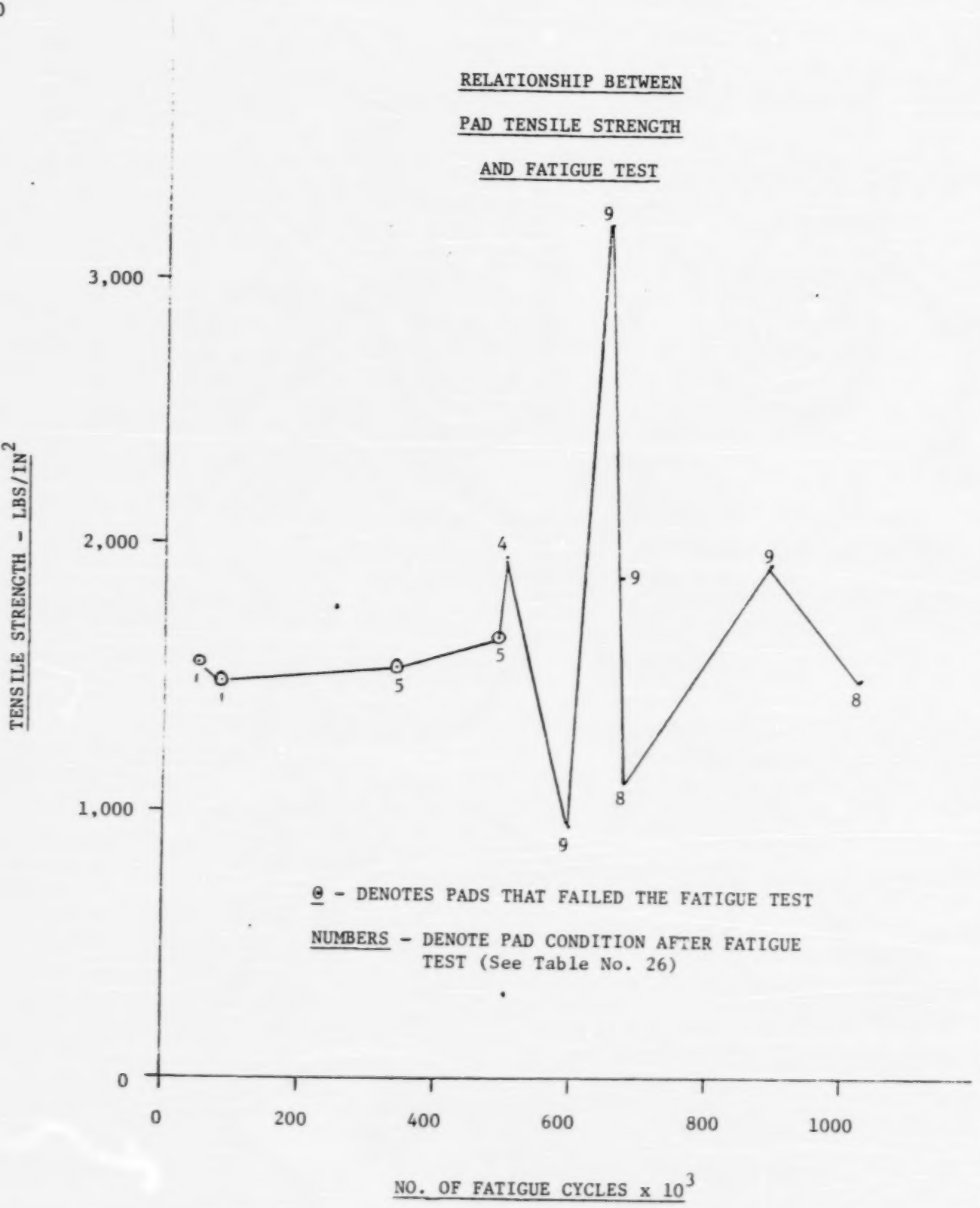

RELATIONSHIP BETWEEN
PAD TENSILE STRENGTH
AND FATIGUE TEST
TENSILE STRENGTH - LBS/IN^2
3,000
2,000
1,000
0
0
200
400
600
800
1000
NO. OF FATIGUE CYCLES x 10^3
Θ - DENOTES PADS THAT FAILED THE FATIGUE TEST
NUMBERS - DENOTE PAD CONDITION AFTER FATIGUE TEST (See Table No. 26)

FIGURE NO. 22

RELATIONSHIP BETWEEN

PAD ABRASION LOSS

AND FATIGUE TEST

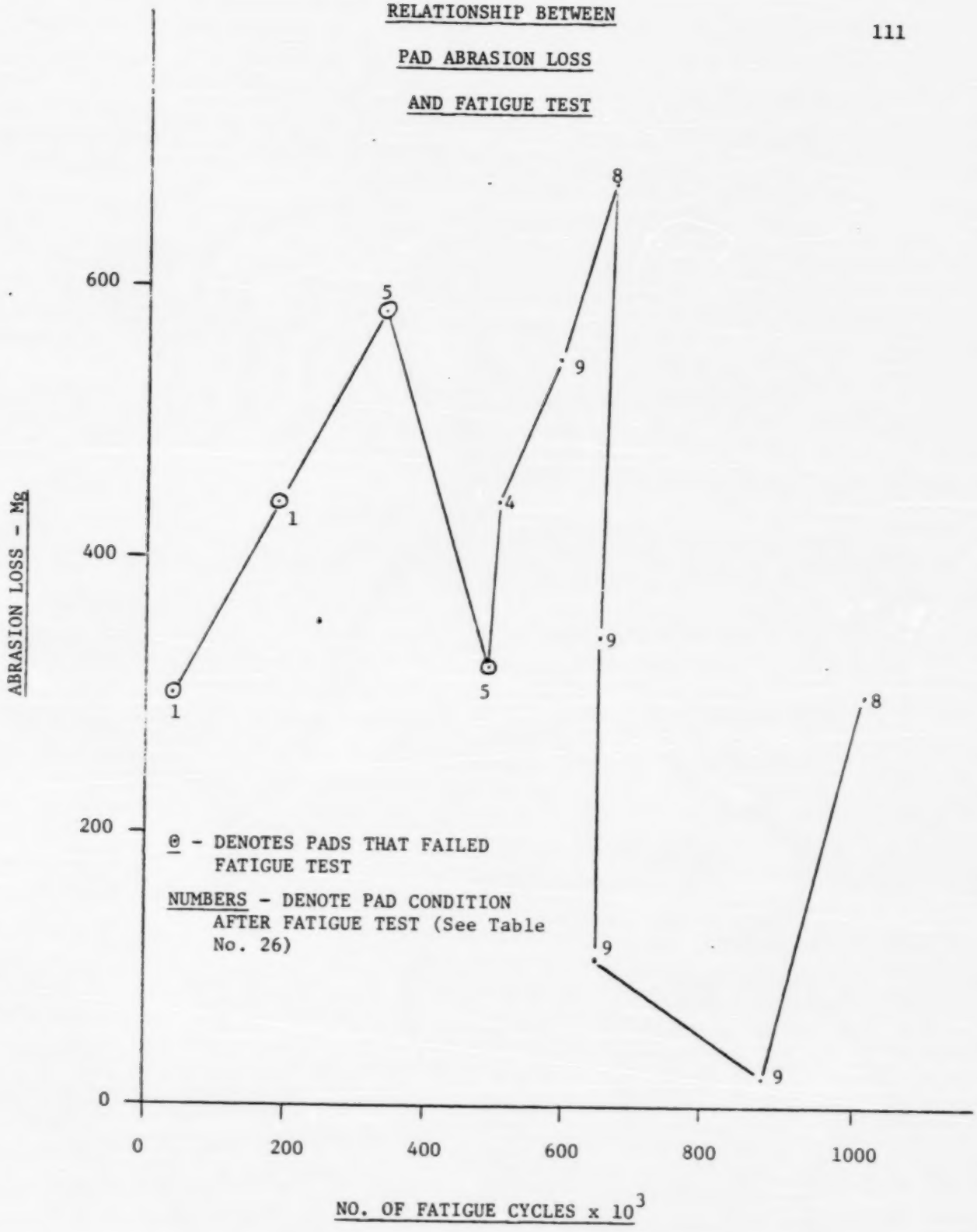


FIGURE NO. 23

RELATIONSHIP BETWEEN

PAD STIFFNESS AND

FATIGUE TEST

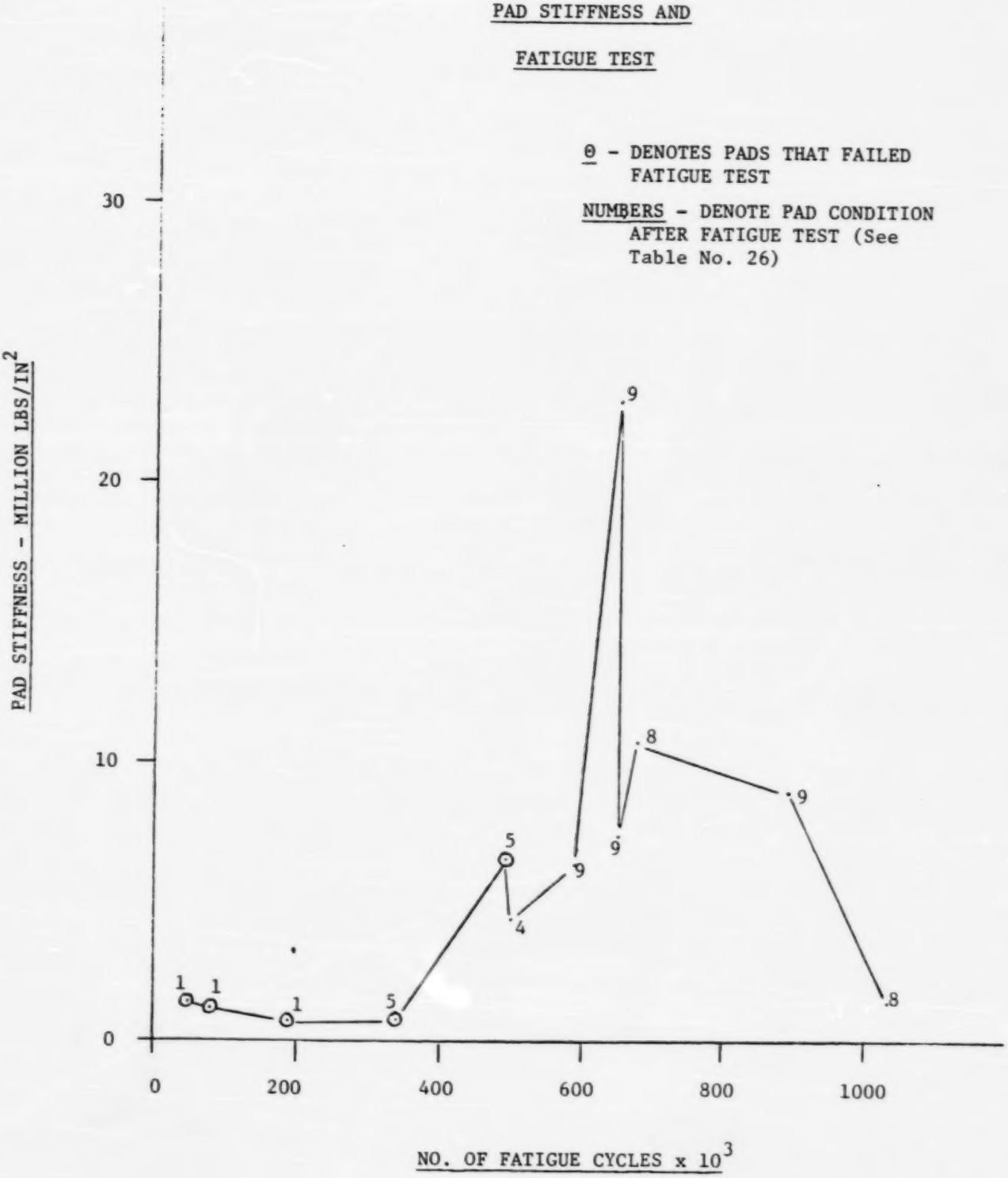


FIGURE NO. 24

RELATIONSHIP BETWEEN

PAD DEFLECTION AND

FATIGUE TEST

Θ - DENOTES PADS THAT FAILED FATIGUE TEST

NUMBERS - DENOTE PAD CONDITION AFTER FATIGUE TEST (See Table No. 26)

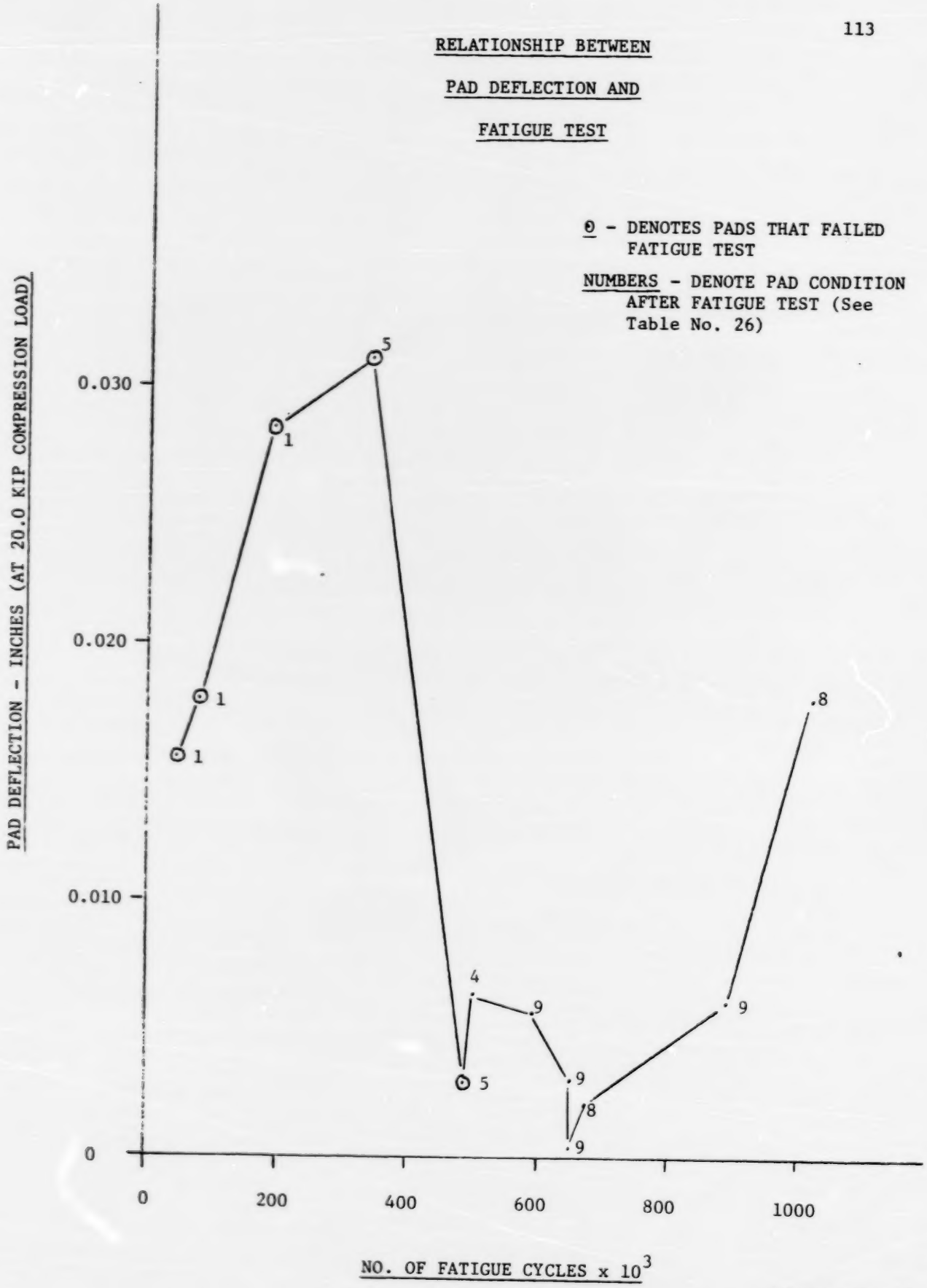
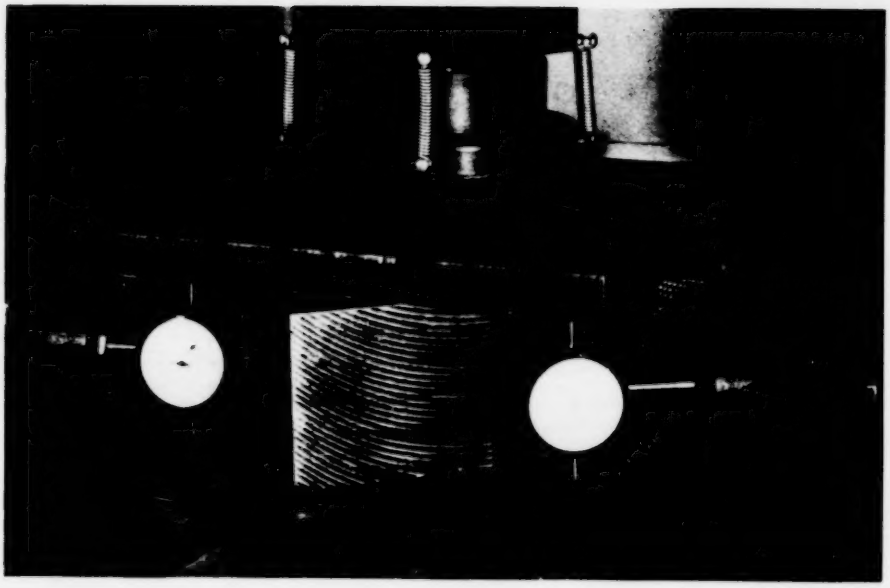
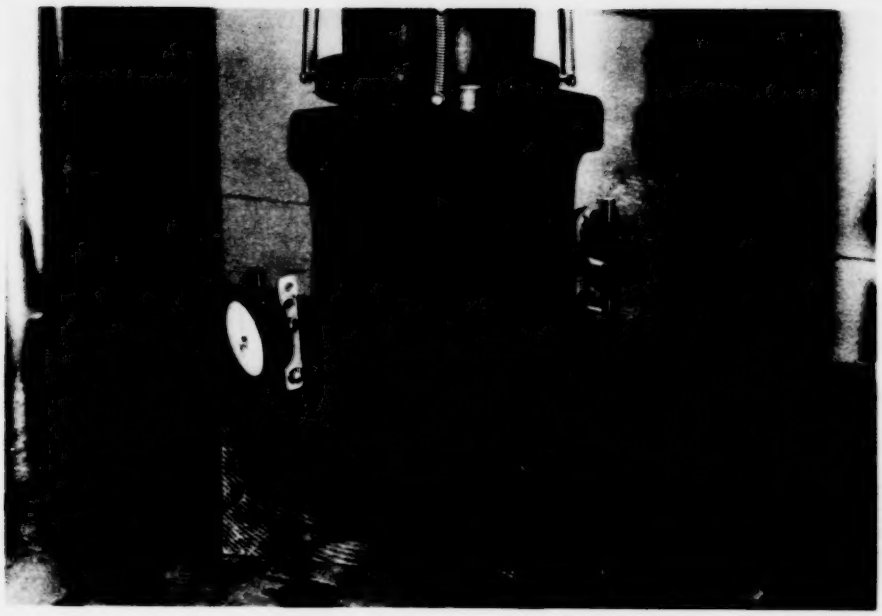


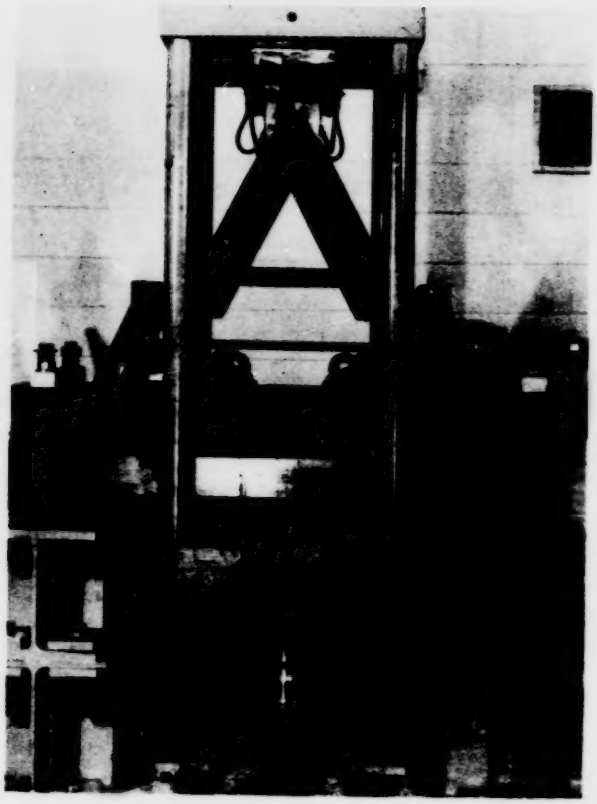
FIGURE NO. 25



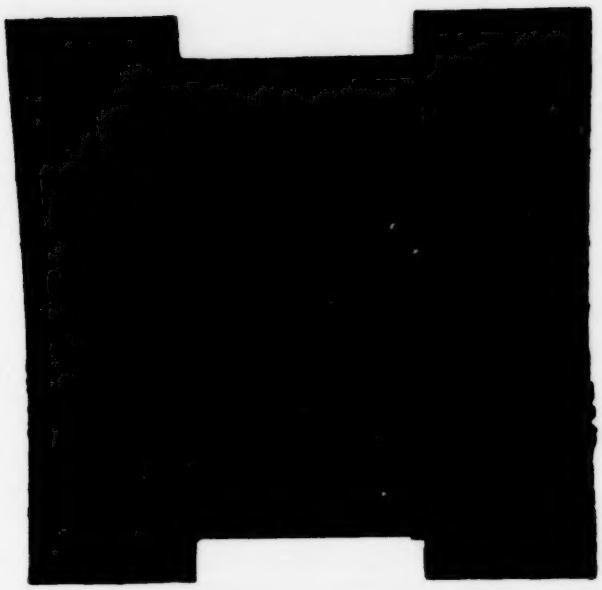
PHOTOGRAPH NO. 1 - Showing the CN's test set-up for load/deflection tests on pads.



PHOTOGRAPH NO. 2 - Showing Manufacturer D's test set-up for load/ deflection tests on pads.



PHOTOGRAPH NO. 3 - Showing CN Research Center's inclined fatigue load testing machine.



PHOTOGRAPH NO. 4 - Showing new pad rated as 10.

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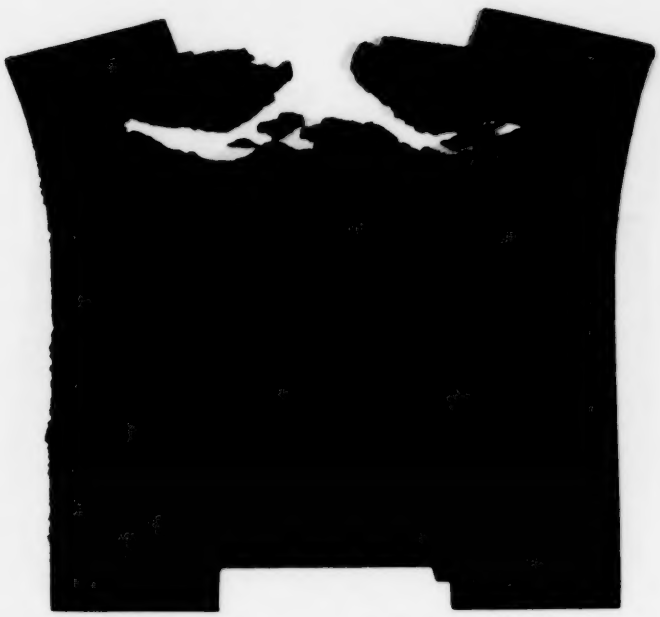

PHOTOGRAPH NO. 5 - Showing used pad (failed) rated 1.